DRYING AND

DEHYDRATION OF FOODS

HARRY W. VON LOESECKE*

Senior Chemist, Bureau of Agricultural Chemistry and Engineering, Agricultural Research Administration, Agricultural Chemical Research Division, U. S. Department of Agriculture, Washington, D. C.

In this war, food is as necessary as bullets.

Claude R. Wickard

* The statements in this publication are made solely upon the responsibility of the author and do not necessarily reflect the official viewpoint of the organization with which he is connected.

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Foreword

The preservation and transportation of foods is always a major problem in time of war. Canning as a means of preservation owes its existence largely to the requirements of Napoleon's armies, and its important development began during the Civil War. Dehydration as a war activity assumed an outstanding place during the first World War, and the present conflict, with its greatly increased demands for transportation, is forcing an enormous expansion of the industry. Fortunately, by virtue of the control of priorities and of finances for new plants, the expansion is being confined largely to those persons who have had experience in food processing and who require only limited amounts of metals and funds to convert their plants to dehydration. Contrary to what happened in 1917, this control has prevented the entry of many unskilled and inexperienced people into the industry. At that time dehydration was a war baby, and the belief that the production of dehydrated foods, particularly vegetables, was highly profitable attracted many to the industry who had but few qualifications.

The place of dehydrated foods in the war effort has long been recognized. In 1864, Prof. E. N. Horsford, in "The Army Ration" wrote:

> "As desiccated vegetables, the water is in large part removed, the bulk correspondingly reduced, and the liability to injury from variations of heat and atmospheric moisture overcome. . . . [Vegetables] are thoroughly cleaned, sliced, dried in a current of heated air, weighed, seasoned and pressed with the aid of a hydraulic press into compact forms, sealed in tin cases, and inclosed in wooden boxes. In this condition they are sent to the field. An ounce is a ration. A block one foot square and two inches thick weighs seven pounds and contains vegetables for a single ration for 112 men."

Except for the omission of a reference to blanching, the description of the processes can be equally applied in a general way to present practices.

Dehydration as a method of food preservation is of unknown antiquity. Natural sun drying preserved many fruits, and grains did not spoil when their moisture content fell below certain levels. Weather conditions in the areas where many people believe the human race originated were ideal for such drying. Long afterward it was learned that milk could be preserved to some extent by being made into butter and cheese, both operations involving some dehydration. Ages afterward, it appears that meat and possibly fish were dried by exposure to the air, especially in places like our western plains where the relative humidity is generally quite low.

All dehydration which depends solely on natural conditions is subject to the possibility of total loss or at least the production of inferior quality because of inability to control the weather. In order to avoid these difficulties, drying equipment has been developed in which the operator, by adjusting air volume and velocity, temperature and relative humidity, has overcome the hazards imposed by the weather.

The dehydration of foods in this country is still practically an infant industry. Dried skim milk in fairly large quantities has been made for a number of years, and dried egg products, domestic or imported, have been used by bakers, confectioners and other manufacturers. No commercial production of dehydrated meat has existed, and as far as known, the Louisiana sun-dried shrimp is the only seafood preserved solely by drying in this country. As late as 1940, dehydrated vegetables were manufactured to the extent of about 5 million pounds. The dried fruits of trade, amounting to some 600,000 tons per year, cannot be considered as dehydrated as their water content is far higher than that of dehydrated products.

The quantities of dehydrated foods estimated to be necessary during 1943, and for which plans for production have been made, are as follows:

Vegetables	355 million pounds
Soups	207
Milk	517
Egg	460
Meat	110
Fruit	50

To obtain these amounts, a large increase in dehydration facilities will be necessary, and for some items, special consideration

must be given to obtaining the raw materials required for the program.

Many questions arise regarding the place of dehydrated foods in peace times. Optimists see dehydrating as replacing canning, and pessimists believe that the products will disappear as rapidly and completely as after the last war. As usual the median position is probably the correct one. That is, dehydrated products will stand or fall, depending on several factors, in their competition with other foods. The outstanding factors are convenience, quality and price.

The saving in weight of foods through dehydration, although of real value, is not as important as is the saving of volume. In some cases, on account of the fact that the dried products tend to curl up, the volume of the dried product is practically the same as that of the original raw material. The difficulty can be overcome by compression, and much research work is now being done to develop satisfactory methods. One of the present limiting factors is the lack of enough presses with adequate capacity and power.

Packaging of dehydrated foods, in the absence of a sufficient supply of metallic containers, presents a series of problems. The ideal package must be moisture- and moisture-vapor-proof, resistant to the penetration of fat or oil, insect- and rodent-proof, and for use in wartime should be made of non-critical materials. The attainment of the ideal is believed to be practically impossible, but some of the laminated containers now in production will meet most of the requirements and can be depended on for most of the services they will be called on to render.

The author of this volume has been closely associated with the research on the dehydration of vegetables carried on by the Department of Agriculture, first as a member of the Dehydration Committee of the Bureau of Agricultural Chemistry and Engineering, and later as a staff consultant in Washington. The information presented is not intended as an operating manual, but only as a general outline of procedure and practices in commercial use.

Robert S. Hollingshead

Assistant Chief, Agricultural Chemical Research Division, Bureau of Agricultural and Industrial Chemistry, U. S. Department of Agriculture, Washington, D. C.

Preface

The purpose of this book is an attempt to place before those interested in food dehydration a compilation of the latest practical information dealing with this subject. The data presented are not considered as giving a complete picture of the science of food dehydration. It was believed that the book would serve best if set forth without attempting an exhaustive treatment of the subject. Then, too, researches in the technology of food dehydration are progressing rapidly, and it would be impossible to keep pace with the strides being made and at the same time present these new data between the covers of one volume so that they serve a useful purpose.

The author expresses his appreciation to those companies and individuals who have kindly lent illustrations, and to those research workers from whose papers he has taken the liberty of presenting data. Every effort has been made to indicate such sources of information.

The author desires to acknowledge his indebtedness to Robert S. Hollingshead, Asst. Chief of the Agricultural Chemical Research Division, Bureau of Agricultural Chemistry and Engineering, and to J. O. Reed, Development Engineer, Bureau of Agricultural Chemistry and Engineering, for their helpful suggestions; acknowledgment is also made to E. M. Mrak of the University of California for much information relative to the drying of fruits.

Washington, D. C.
June 1, 1943

H. W. von Loesecke

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Chapter 1

Types of Dehydraters

Prescott and Sweet[1] have defined dehydration when applied to foods as "the process of removal of surplus water without destruction of cellular tissues, or impairment of the energy values."

The preservation of foods by drying is one of the oldest methods used by man. In the early days of the Massachusetts colonists, cooked corn was preserved by drying. Salted, dried fish was also produced, and it constituted the first export business of the American colonies. In the arid regions of the interior of the United States, the Indians and early settlers dried buffalo meat and beef by cutting it into thin strips and hanging it in the sun. The product was known as jerked beef, and is prepared even today by certain Indian tribes of the Southwest. In other parts of the country, especially in the interior of California where the sun is hot and rainfall low, the drying of such fruits as prunes, grapes and peaches was found profitable. During the Civil War, troops were supplied with dried vegetables, soup mixtures, apples and peaches. Dehydrated foods were also found in the rations of troops in the Boer War.

The dehydration industry has never become as important in the United States as it has in Continental Europe. The first World War acted as an impetus to expand dehydration in America, and from 1917 to 1919 a considerable amount of research and increased production of dried foods took place. According to Nichols and his associates[2], nearly nine million pounds of dried potatoes, onions, carrots, turnips and soup mixtures were shipped to the United States Army overseas. At that time, the technique of drying vegetables was not as well understood as it is today, and many of the products proved unsatisfactory.

Following the World War, production of dried foods decreased

[1] Prescott, S. C., and Sweet, L. D., "Commercial Dehydration: A Factor in the Solution of the International Food Problem," *The Annals of the Am. Acad. Polit. and Soc. Sci.* Pub. No. 1294 (May, 1919).

[2] Nichols, P. F., Powers, R., Gross, C. R., and Noel, W. A., "Commercial Dehydration of Fruits and Vegetables," *U. S. Dept. Agr. Bul.* 1335 (1925).

because the civilian population did not care for them. A few concerns dehydrating foods developed a considerable mail-order business, while others stressed the "health" virtues of dehydrated vegetables. About 1930 there developed an interest in dried Jerusalem artichokes to be used by diabetics. The artichoke contains inulin, a carbohydrate that is hydrolyzed to the sugar levulose. It was erroneously believed that levulose could be better tolerated by diabetics than any other common sugar.

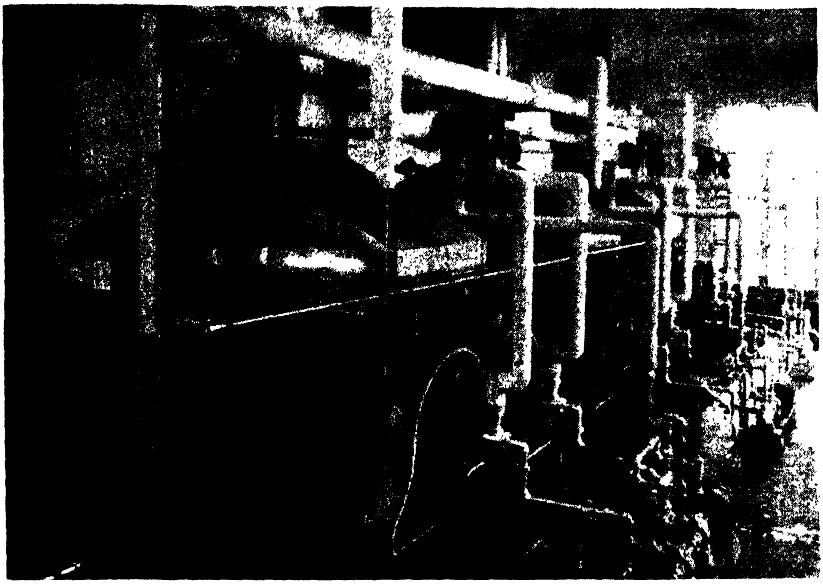
The production of dried onions, garlic, parsley and chili survived the post-war dehydration period and became a stable industry.

With the coming of the Second World War, the dehydration industry has taken on a new life. Today, the industry is greater than it has been at any time in its history and it is expanding rapidly. After the war ends, it is not likely that this industry will collapse so completely as it did after the First World War. A starving world will have to be fed and the problem of transporting huge quantities of food will be so acute that it will be necessary to reduce the bulk of such foods to a minimum. This is best accomplished by drying and subsequent compression of the dehydrated product.

Types of Dryers

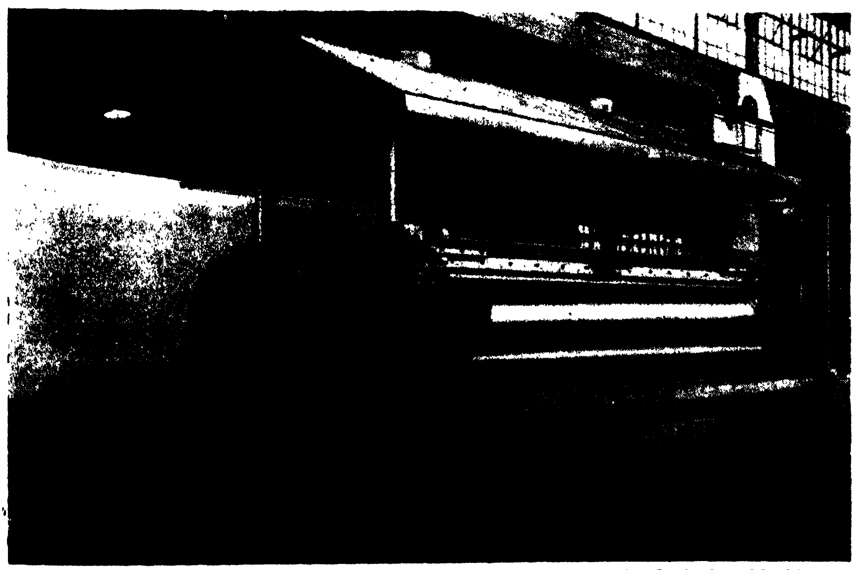
There are many types of dryers used in the dehydration of foods, the particular type selected being governed by the nature of the commodity to be dried, the desired form of the finished product and labor and operating conditions. Although there are dozens of so-called improved dehydraters being offered, many of a rather radical nature, the discussion here will be confined to those types of conventional design that have been used in practice over a period of many years. Many of the new types of dehydraters may have merit, but they must first be proved in actual commercial operation.

Drum Dryers. These may be atmospheric or vacuum, consisting of steam-heated drums 2 to 6 feet in diameter to which the material to be dried is applied by feeding devices. The drums may be either single or double (Figs. 1 and 2). The drums revolve, and before they have made one revolution, the material is dry and is removed by a "doctor blade," or scraper. Conveyors are generally provided to remove the dry material from the vicinity of the drum. The wet material is fed onto the drums by any one of several different arrangements: there may be a shallow pan beneath the drum, and as



Courtesy Buffalo Foundry & Machine Co.

FIG. 1. An installation of three atmospheric double-drum dryers used for drying skim milk; they have a combined capacity of 1000 lbs per hour.



Courtesy F. J. Stokes Machine Co.

FIG. 2. Another view of a drum dryer.

the drum revolves it receives a coating of the liquid material in the pan; there may be a spray feed consisting of a projection roll revolving at high speed which throws a spray of liquid material upon the heated drums; or the material may be fed onto the drums through a perforated pipe, or through a jacketed hopper provided with an agitator and a rotor.

Drum dryers are found suitable for drying milk, certain vegetable juices, cranberries, bananas, and as a preliminary dryer for meat. They may also be utilized for drying vegetables which are to be used in the making of purees. They are not suitable where it is desired to obtain anything but powder or flakes.

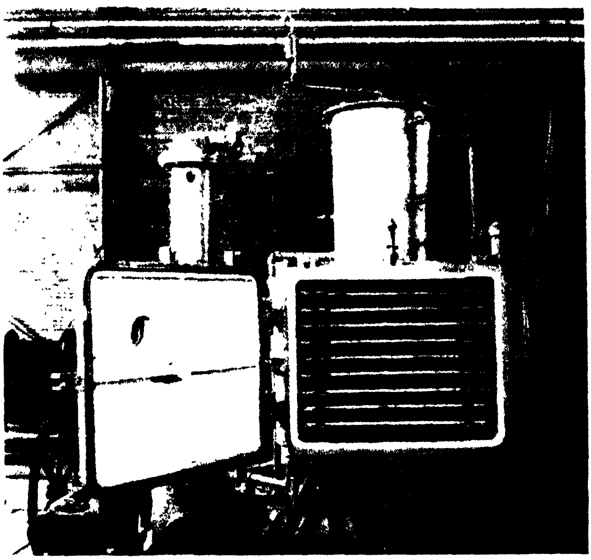
In vacuum drum dryers, the drying is conducted under a vacuum by inclosing the drum in a housing of sufficiently rugged construction to withstand a high vacuum. The drums are heated by steam to give the desired temperature. This type of drum dryer is used in those instances where the product may be injured by drying in contact with air.

The capacity of drum dryers is proportional to the effective drying area, *i.e.*, the total surface from which drying can take place ($\pi DL \times$ rpm). In general, steam consumption amounts to from 1.7 to 2.0 pounds per pound of water evaporated. Usually, from 2 to 8 pounds of water may be evaporated per hour per square foot of drum surface, according to the steam pressure on the drums.

Vacuum Shelf Dryers. These are advantageous for rapid drying at low temperatures. They consist of a heavy shell to withstand a high vacuum, and a series of shelves heated by hot water, or steam, Dowtherm or oil (Fig. 3). Vacuum dryers require considerable expensive accessory equipment, such as vacuum pumps, condensers and ejectors. The weight of material produced per pound of metal in the dryer is extremely small and drying costs are higher than in other types of dryers. However, some authorities state that the increased drying costs are offset by the improved quality of the product and especially by the greater vitamin C retention. Furthermore, it is possible to dry to a lower moisture content in vacuum dryers than in atmospheric dryers, and it is known that low moisture content in the case of many products is an important factor in the keeping quality.

At present, vacuum shelf dryers are used only for limited production of dehydrated foods.

Continuous Vacuum Dryers. These are still more or less in the experimental stage. The continuous vacuum dryer has an advantage over the shelf vacuum dryer in that the latter is a batch process and thus requires more labor than the continuous dryer. Continuous vacuum dryers may consist of a travelling mesh-metal belt or trays on trucks inclosed in a shell of heavy construction to withstand a high vacuum. If a belt is used, it may be arranged in several layers within the dryer so that the material will drop from the top belt to the one below and thus travel back and forth through the dryer. Such dryers are provided with air locks at both the charging and discharging ends to prevent breaking the vacuum during operation. Dehydration in this type of dryer is a matter of minutes, as compared to hours in atmospheric dryers.



Courtesy J. P. Devine Mfg. Co.

FIG. 3. Vacuum Shelf Dryer.

It has been found that, in general, all vacuum dryers when used for dehydrating foods will operate more efficiently if a pulsating vacuum is used, *i.e.*, the vacuum is periodically broken, thus sweeping out the moist air. However, if the material and interior of the dehydrater are below the dewpoint of the humid air, condensation of moisture will take place. Should a method be devised so that the

small amount of air within the dryer could be recirculated during the dehydration period, it would not be necessary to break the vacuum.

Spray Dryers. In this method, the material, reduced to the form of a solution, suspension, slurry or sludge, is finely atomized in a gaseous heating medium such as air. The air transmits its heat to the individual particles of spray, and the moisture is evaporated, leaving behind the solids as a powder floating in the air stream. The method of atomizing varies according to the ideas of different man-

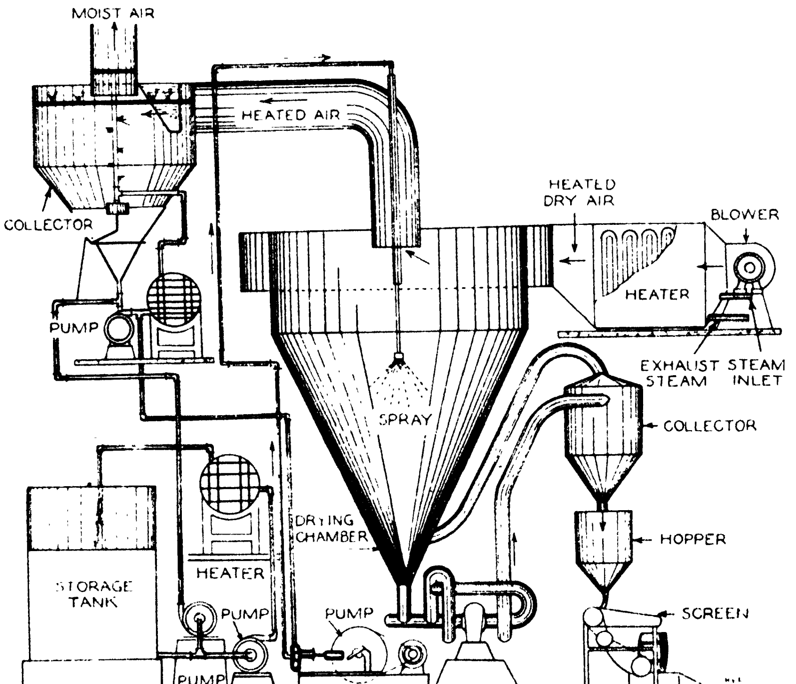


FIG. 4. Spray dryer used for milk.

ufacturers of spray dryers. Atomizers may consist of spray wheels, discs, cups, nozzles, etc., the purpose being to obtain a mist of the material (Fig. 4). The atomizer may be located either at the top, side or bottom of the drying chamber.

Air for spray drying may be heated by steam coils or by direct products of combustion obtained from gas, fuel oil or coal. In the case of coal, when the dryer is first started the flue gasses are by-passed to insure clean combustion products.

In spray dryers, the sensible heat loss in the waste air is usually quite high and thus spray drying is confined to those cases where short time of drying is particularly desirable. Efficiency of the dryers would be increased by recirculating part of the exhaust air and boosting its temperature by adding hot, fresh air. However, this is seldom possible because the exhaust air cannot easily be freed of suspended dried material, which would be overheated by contact with the hot, fresh air acting as a booster. Thorough cleaning of the exhaust air by scrubbers would be too expensive, and scrubbing would also reduce the temperature of the exhaust air. In the Peebles design, part of the exhaust air is withdrawn from the top of the spray chamber and returned to the bottom. In this case, the exhaust air is not reheated.

Table 1 gives performance data on spray dryers. These data are from Folger and Kleinschmidt,[3] who point out that the results show only the thermal efficiency of the spray chamber. "Losses incident to heating the drying gas, such as stack loss, condensation, and furnace and duct radiating, must be deducted in determining the overall thermal efficiency."

Table 1. Performance Data of Commercial Spray-Drying Equipment* of Representative Materials[3]

Type of Material	Solids in Spray (%)	Water in Product (%)	Temp. inlet gas (°F)	Heat required per lb water evaporated† (Btu)
Organic	10	2	300	2250
Organic	35	3	325	3800
Organic	33	2	350	3300
Organic	10	2	450	2700
Organic	65	15	375	3000
Organic	55	4	750	2250
Inorganic	60	4	750	2500

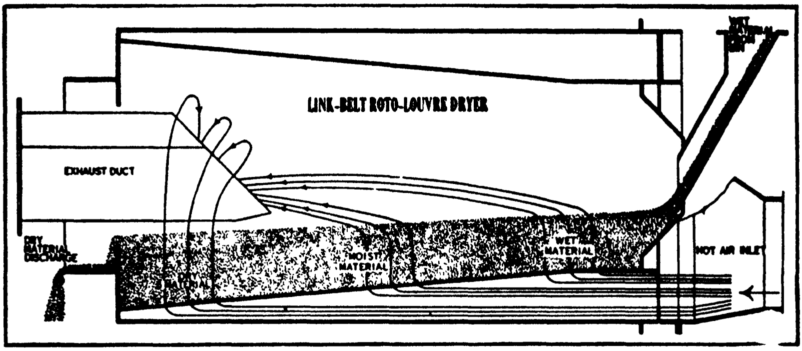
*Four different commercial types and 5 sizes of dryers are represented by the data given.

†Btu's in drying gas above 65° F. datum temperature at entering spray chamber.

According to Folger and Kleinschmidt,[3] a spray dryer approximately 10 feet in diameter and with a heat requirement of 2100 to 1600 Btu per pound of water evaporated would cost, under normal economic conditions, from $20,000 to $30,000 installed. Fan horsepower required would range from 25 to 75 hp. For pumping and atomizing the spray liquor, an additional 5 to 15 hp would be necessary. Labor would require one operator and a helper.

[3] Folger, B. B., and Kleinschmidt, R. V., "Spray Drying," *Ind. Eng. Chem.*, 30, 1372 (1938).

Spray dryers are used for drying whole eggs, egg yolk, blood albumen and milk. They are not suitable for drying vegetables, but may be used for certain vegetable and fruit juices.



Courtesy Link-Belt Company

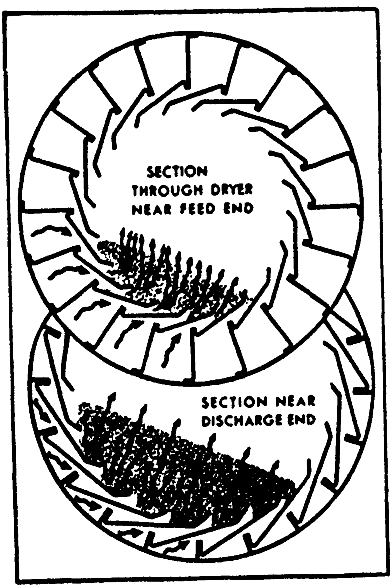


FIG. 5. The longitudinal section through the Link-Belt Roto-Louvre dryer illustrates the flow of material and gases, and how the louvres taper toward discharge end of drum.
Cross-sectional view, showing arrangement of louvres in the Link-Belt Roto-Louvre dryer.

Rotary Dryers. These are revolving shells provided with devices to keep the material moving so that it will not stick to the sides of the dryer or mat together. They are not generally used for food products, with the possible exception of meat. Sliced vegetables, such as carrot slices or spinach, may "ball up" and lose their original shape. Drying is accomplished by the material coming into contact either with steam-heated tubes inside the dryer, or with air heated by direct oil heat.

The Roto-louvre dryer was developed in Sweden primarily for use in the pulp, paper, and lumber industries.[4] Louvre fin plates are attached to the shell of the dryer dividing it into a number of small compartments. Tangential louvre plates are in return attached to these fin plates. The combination of plates forms air channels for the introduction of hot gases or air to the dryer, and the space between the overlapping louvre plates permits the hot air to pass through these channels and up through the material in the dryer (Fig. 5).

Rotary dryers are widely used in preparing feeds from waste citrus fruits and sweet potatoes.

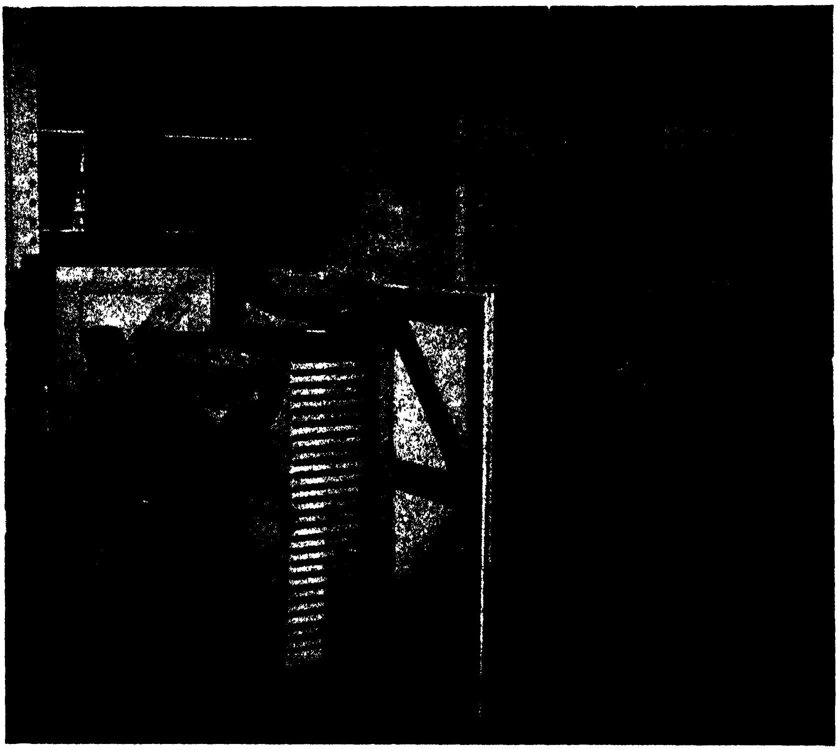
Cabinet or Compartment Dryers. These consist of a drying chamber which may be divided into several compartments each holding one or two stacks of trays. The trays are mounted on trucks or dollies for convenience in handling. Air having a movement of from 600 to 1200 linear feet or even more per minute is carried from the heaters (preferably fin coils) through a main duct from which it can be diverted to each compartment. Circulation is usually across the trays, although there are some types in which air is forced through the trays. In the latter type, drying is more rapid. Air is discharged from each compartment into another duct where it can either be discharged from the dryer or reheated and used again.

Although cabinet dryers are most commonly heated by steam coils, the shortage of boilers during the present war has stimulated engineers to design cabinet dryers that can be heated with coal, wood, oil or gas. Such heat, with the exception of gas, is indirect to prevent damaging the material with the products of combustion. The difficulty of heating with coal or wood is proper temperature control.

Cabinet dryers are particularly suitable for drying fruits and vegetables and where operation of the dehydrating plant is not continuous, or where one wishes to start production on a small scale. They may be quite cheaply constructed and with a minimum of strategic material. A cabinet dryer of about 1000 sq ft of tray area may be completed, with heating unit and fans, for about $1200.00. Such a cabinet would handle from 1000 to 1500 pounds of fresh pre-

[4] Erisman, J. L., "Roto-louvre Dryer," *Ind. Eng. Chem.*, 30, 996 (1938).

pared vegetables every 6 or 7 hours. Fig. 6 shows such a cabinet dryer which utilizes commercial unit heaters and blowers. The capacity of the dryer depends upon the size of the unit heater. A heater approximately 8 ft wide, meeting the capacity requirements, will be sufficient for a cabinet dryer having about 1000 sq ft of tray surface. The heater unit in the dryer shown is of steel. The cabinet



Courtesy U. S. Dept. of Agriculture. (Photograph by Lee)

FIG. 6. A stack of trays holding the prepared vegetable is run into a cabinet dryer.

is of a wood-frame construction with cement-asbestos board lining the interior, and insulating board (such as Celotex) being used to seal the exterior. For a more permanent installation, masonry construction can be used. About 25 boiler horsepower will be required to heat such a cabinet.

Kiln Dryers. These are sometimes called "evaporators" and in the past were commonly used for drying apples. There are some kilns at present in use for drying vegetables, but they are not con-

sidered satisfactory for this purpose because of the large amount of handling necessary and because of the long drying period.

The kiln consists of a two-story arrangement, the lower floor or cellar being provided with a stove or furnace (usually oil-fired in the western part of the country) and a fume pipe. The heating pipes of the furnace are arranged so that the warm air is equally distributed underneath the ceiling of the cellar. The ceiling consists of narrow slats and the air passes between the slats into the first floor. The material to be dried is spread evenly to a depth of 4 to 8 inches (10 to 12 lbs per sq ft) on the slatted floor. To facilitate air movement, intake ducts are cut into the lower part of the cellar walls, and on the first floor. The saturated air is passed outside. Air movement, with this arrangement, depends upon convection and of course passage of the hot air through the material cannot be controlled. Some kilns are therefore provided with fans.

It requires from 12 to 14 hours to dry potatoes in a kiln (against from 6 to 7 hours in a cabinet or tunnel dryer) and it is necessary to turn the material several times during the drying operation.

In some instances, kilns are provided with trucks holding trays of the material being dried. In this case, it is necessary to shift the trays several times during drying to obtain uniform dehydration.

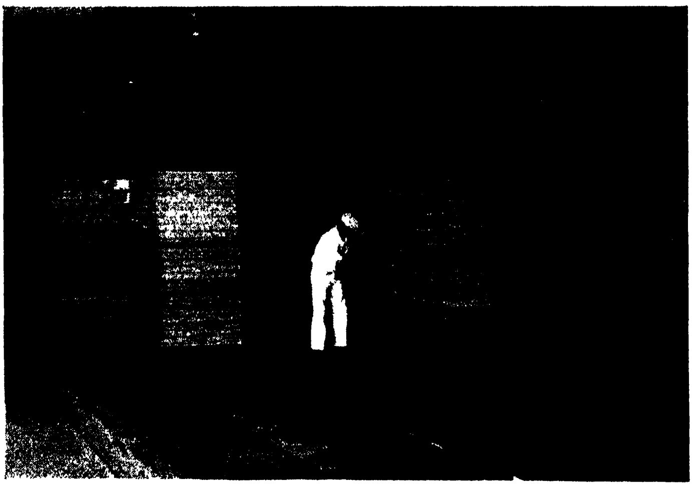
Fuel requirements for kilns are about 1 gal of oil (assuming the oil has 160,000 Btu per gal) to dry about 6.5 lbs of apples.

Tunnel Dryers. These are the types now most widely used for dehydrating fruits and vegetables. In the more common type, drying takes place in tunnels about 35 or 40 feet long and 6 ft high by 6 ft wide. These measurements are not standard, but the length of the tunnel rarely exceeds 50 ft. The material to be dried is loaded upon slatted wooden trays, or metal trays, which are stacked on trucks. To prevent the material from sticking to the trays, some dehydrators apply slab oil (a light mineral oil) with a paint brush. After application it is preferable to run the empty trays through the tunnel to get rid of excess oil. The trucks and trays should fit the tunnel snugly so that all the air will pass between and across the trays.

The loaded trucks are introduced through a door at one end of the tunnel, and the trucks of dried material removed through a similar door at the opposite end. Air movement in the tunnel may be in the same direction as the trucks (parallel-flow); opposite to

travel of the trucks (counter-current); or parallel flow at the entrance, or wet end, and counter-current at the exit, or dry end, with air exhaustion at the center (center-exhaust type).

Another form of tunnel dryer is the so-called draper type. This consists of a mesh belt travelling through a tunnel. In the most common form of draper dryer, the air is forced through the material, thus permitting heavier loadings than in tray and truck dryers. Draper dryers also call for less labor than tray and truck tunnel dryers, for in the former the belt is automatically loaded.



Courtesy U. S. Dept. of Agriculture. (Photograph by Lee)

FIG. 7. Racked high, trays of cored, sliced, blanched cabbage are pushed into a drying tunnel.

Parallel-flow tunnels are considered the least efficient for dehydrating vegetables, and sufficiently low moisture content of the finished material cannot be economically attained in them. If this type is used, it is necessary to finish drying in bins provided with a slight updraft of warm, (110-120° F) dry air. It takes from 4 to 6 hours' treatment in such bins to dry to the necessary moisture content. Tentative results indicate that loss of vitamin C in such drying bins is not significant. The use of finishing bins is not confined to operations where parallel-flow tunnels are used; bins may also be utilized in the case of counter-current or center-exhaust tunnels if the dehydrator wishes to increase the capacity of his dryer.

The center-exhaust tunnel is comparatively new and has resulted

from the work of Eidt in Canada.[5] It appears to be more efficient in many respects than the counter-current type generally used in the United States. In reality, the center-exhaust tunnel is a two-stage dryer because, as just pointed out, the heated drying air enters both ends of the tunnel.

In some instances, two or more separate tunnels are used, the first operated as parallel flow provided with air of high velocity. Here the moisture content of the material is reduced to about 50 per cent. The product then enters one of the secondary tunnels which operates as a counter-flow tunnel, and where dehydration is completed. More secondary tunnels are necessary than primary because dehydration is about three times longer in the former.

In the case of the center-exhaust tunnel, parallel flow at the wet end is particularly efficient because in the initial stages of drying, when the product is wet, high temperatures can be used without injury to the material. Evaporation of moisture from the product results in cooling, so that the temperature of the material being dried very nearly approaches that of the wet bulb. In this first stage, over 90 per cent of the water may be evaporated.

In the second stage, where air flow is counter-current, the temperature must not be high enough to scorch the material. In this stage no cooling effect is obtained by evaporation of water from the material because over 90 per cent of the water has already been removed. For most efficient operation, the secondary tunnel should hold about twice the number of trucks as the primary tunnel.

In the first stage of drying with this type of tunnel, a high volume of air flow is required to increase the drying rate of the wet material and to carry large quantities of heat necessary for drying. However, in the second stage of drying the quantity of water to be removed is small and air velocity has little effect on the drying rate.

The main purpose of the center-exhaust tunnel is to decrease drying time and hence increase the capacity of the tunnel. If this type is used for slow-drying products, however, the increase in tunnel capacity over that of the counter-current tunnel may be insufficient to offset increased cost and operating difficulties of the center-exhaust tunnel. Fig. 8 shows an Eidt center-exhaust tunnel of the type used in Canada.

[5] Eidt, C. C., "Principles and Methods Involved in Dehydration of Apples," *Dom. of Canada. Dept. Agr. Techn. Bul.* 18 (1938).

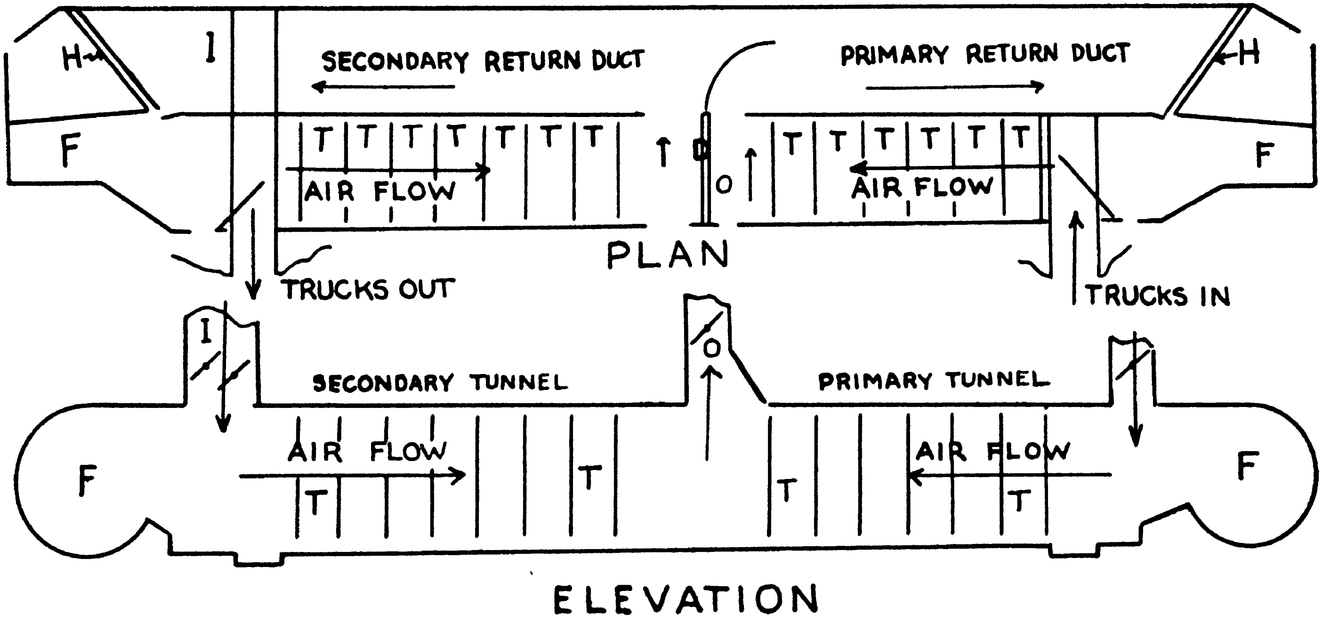


FIG. 8. An Eidt center-exhaust tunnel dryer: in the figure, F is a fan; H, fin coils; I, an inlet; O, exhaust air; T, position of trucks containing material to be dried; D, sliding door for trucks. In the primary tunnel, dehydration is by parallel flow, and in the secondary tunnel by counter-current flow. With this arrangement, higher drying temperatures can be used in the primary tunnel. (From Eidt, C.C.: "The Mechanics of Dehydration," *Food in Canada*, 2, No. 12, p. 17 (1942)).

The counter-current tunnel is in common use in the western states for drying prunes, grapes and vegetables. The limiting factor in this type of tunnel is the temperature at the hot (dry) end of the tunnel, since this temperature must not exceed a certain critical point above which the product being dried will be damaged.

Heating System of Tunnel Dryers. In the western states, direct gas heating is generally used, *i.e.*, the combustion products are mixed and circulated with the drying air. The sulfur in the natural gas has no effect on the quality of the product. In some instances direct oil-fired heating is utilized, but there is an element of danger in such installations because of the possibility of incomplete combustion of the fuel, which causes sooting. This danger has been eliminated in the case of spray dryers by the installation of a photoelectric cell which shuts off the burner and spray feed pump if the burner shows improper combustion. When the burner is first started, there is invariably sooting, but during the run careful regulation of the burners should avoid subsequent trouble. Indirect oil heating is also used, and in this case an extensive system of sheet-metal flues is necessary. A similar flue installation is required if coal or wood is used for heating. The flues should be so constructed that they can be dismantled and cleaned. In indirect heating, fuel efficiency is about 60 per cent as compared to 100 per cent by direct heating.

If tunnels are steam-heated, from 6 to 10 bhp of steam generating capacity is required per ton of material to be dried each 24 hours.

Air Flow in Tunnel Dryers. This will vary from 160 to 1200 or more linear feet per minute. If proper air velocity is attained there will be miniature cyclonic disturbances about the material being dried; but if air flow is too low, the air tends to "slip" over the material. Most dehydration engineers believe that air flow should not be less than 600 linear ft per min and preferably 1000 linear ft per min. However, if flow of air is through the material, velocities in the neighborhood of 200 linear ft per min are considered sufficient. In the case of the center-exhaust tunnel; the air velocity will be about 480 linear ft per min in the first section, and about 160 in the second. As previously mentioned, air velocity is not of such importance after about two-thirds of the water has been evaporated from

the material. Actual velocities between trays will be higher than those previously mentioned.

In the center-exhaust tunnel, there may be danger of disturbing the material, especially when it consists of leafy vegetables, if the air is removed either at the top or sides of the tunnel. A better method of air exhaustion in this type of tunnel is through floor ports, thus creating a downward pull which tends to hold the material on the trays.

Fans. Great care should be taken in selecting the proper fan, and anyone contemplating building a tunnel should place full data in the hands of a fan manufacturer and allow him to specify which fan he is willing to guarantee to do the required work at the best obtainable economy. Propeller fans are not efficient because of high static pressure in the primary tunnel, and because they are noisy. If noise is not objectionable, propeller fans are satisfactory for cabinet dryers.

Recirculation of Air. For the sake of economy, tunnel and cabinet dryers should be provided with means of recirculating the air after it has passed over the material being dried. The amount of air recirculated will determine the drying rate as well as the cost of drying. In general, about 50 to 75 per cent of the air may be recirculated. If none of the exhausted air is recirculated, drying time will be shortened, but cost of drying will be higher than if part of the air is recirculated. The more air recirculated, the slower the drying. In a counter-current tunnel where vegetables are being dried it is generally advisable to maintain a 15-degree wet bulb depression at the cold (wet) end of the tunnel. Such measurements are made by placing a wet- and dry-bulb thermometer in the exhausted air after it has passed over the material. Proper wet-bulb depression is controlled by recirculating the exhausted air. The difference in reading between the wet and dry bulb will be a measure of the relative humidity (Fig. 9). In the case of vegetables in a tunnel dryer, relative humidity at the cool (wet) end of the tunnel will be around 20 to 25 per cent. However, when prunes, grapes or apples are being dried, the relative humidity at the cool end of the tunnel would be between 50 and 60 per cent. These high humidities in the case of fruits have been found necessary to prevent "case hardening" (p. 88). This trouble is not generally encountered in vegetables, with the possible exception of potatoes.

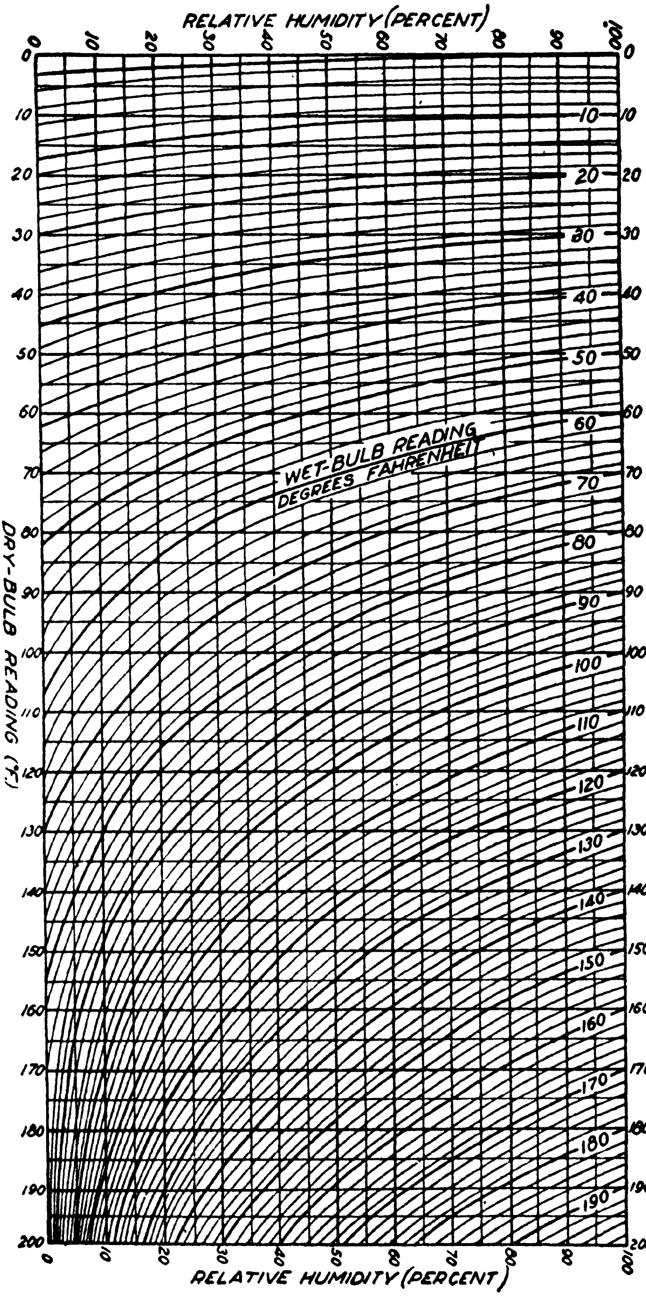


FIG. 9.* Relative humidities corresponding to wet- and dry-bulb temperatures (based on "Psychometric Tables for Obtaining the Vapor Pressure, Relative Humidity, and Temperature of the Dew-Point," U. S. Weather Bur. WB-235, 1910, by C. F. Marvin, and on Figure 1 in "Principles of Drying Lumber at Atmospheric Pressure and Humidity," *U. S. Forest Serv. Bul.* 104, 1912, by Harry D. Tiemann).

From Chace, Noel and Pease: "Preservation of Fruits and Vegetables by Dehydration," *U. S. Dept. Agric. Circ.* 619 (1942).

* *A Relative Humidity Chart, compiled by Dr. H. J. Garber, 18×30 inches, may be obtained from the* ***Reinhold Publishing Corporation*** *for a nominal charge.*

Calculations for Designing a Tunnel Dryer

It is difficult, if not impossible, for one not versed in engineering, and especially ventilation engineering, to design a tunnel dryer that will function with the maximum of efficiency and economy. However, rough approximations can be made of the characteristics of a dryer, based on the nature and quantities of the materials being dried. It should be noted that when a dryer is to be used for several materials, separate calculations must be made for each. For example, if a dryer is to be built to dry 30 tons of potatoes a day, it will not dry 30 tons of cabbage a day and will dry more than 30 tons of prunes.

As an illustration of the factors to take into consideration in designing a tunnel dryer, let it be assumed that it is desired to build a counter-current tunnel dryer, with recirculation, having a capacity of 10 tons of prepared potatoes per 24 hrs. It will be supposed that the temperature of the outside air is 60° F. From practical experience, it is known that if air is heated to 150° F and has a temperature drop of 35° in passing through the tunnel and a humidity at the discharge end not exceeding 20 per cent, the drying period will be about 6 hours. It is also known that about 23 lbs of dried potatoes will be obtained from 100 lbs of fresh prepared tubers.

First, it will be necessary to know how much tray surface is necessary to spread the potatoes. Potatoes may be spread at the rate of $\frac{3}{4}$ to $1\frac{1}{4}$ pounds per sq ft. Taking an average of 1 lb per sq ft, the loading area needed will be 20,000 sq ft $\left(\textit{i.e.},\ \frac{\text{Total load}}{\text{Loading rate per sq ft}}\right)$ Since it requires but 6 hours to dry a batch of potatoes, the 10 tons can be handled in four runs, and therefore the 20,000 sq ft becomes 5,000. If trays $3' \times 3'$ are used on trucks and each truck holds 2 stacks of trays 25 high, the spreading area per truck will be 450 sq ft. It will thus require 11 trucks and these trucks will have sufficient area to hold 5000 lbs of potatoes, which will dry in 6 hours.

It will next be necessary to know the cross-section area of the tunnel. If the vertical space allowed for each tray is 3 in, and 1 in of this represents the thickness of the tray, there will be a 2-in opening between each two trays, or 24 sq ft of free cross-sectional area through the trays. There will be one-half a sq ft free area above

and below the trucks, and 1 1/9 sq ft of free space between the trucks and side walls. Adding this to the 24 sq ft, there is obtained a total of 26 1/9 sq ft of free cross-sectional area.

If the tunnel is to have a capacity for drying 5000 lbs of potatoes every 6 hours, and there will be obtained a yield of 23 lbs of dried tubers per 100 lbs of fresh, 5000×0.77, or 3850 lbs of water will be evaporated each 6 hours. This is an average of 11 lbs of water a minute. It will be necessary, therefore, to supply enough heat to evaporate this quantity of water. The requirement for sensible heat will be 1 Btu per pound of water evaporated from the material per degree increase in its temperature. Now, it has been assumed that the tubers entering the tunnel will have a temperature of 60° F, and that when they are dried they will have the same temperature as the dry end of the tunnel, namely 150° F. The sensible heat requirement is therefore 90 Btu (*i.e.*, 150° − 60 F°). For the purpose of the present calculations, the latent heat of evaporation can be considered as 1000 Btu per pound of water evaporated.* It follows then that the total heat required per pound of water evaporated, under the conditions that have been assumed, will be $90+1000$, or 1090 Btu. For 11 pounds of water evaporated per minute, as pointed out above, total heat required would be 1090×11, or 11,990 Btu per min. Actually the amount of heat supplied by the fuel will have to be greater than this because of loss of heat in the drying system. Thus, it will be necessary to take into account the thermal efficiency of the drying system, *i.e.*,

Table 2. Assumed Thermal Efficiencies of Different Heating Systems.
(Chace, Noel and Pease, *U. S. Dept. Agr. Circ.* 619, 1942)

Heating System	Thermal Efficiency: Drying Chamber, tunnel or cabinet (%)	Heater (%)	Whole system (%)
Direct heat	40—50	90—100	36—50
Direct radiation	40—50	80— 90	32—45
Indirect radiation	40—50	60— 70	24—35

the relationship between the amount of heat actually used in evaporating the water from the potatoes and the total amount of heat generated by the fuel used to heat the tunnel. Thermal efficiencies for different systems are given in Table 2.

Let it be assumed that the tunnel in our problem will be heated

* In actual practice, this ranges from 1500 to 6000 Btu.

by direct radiation. According to Table 2, the thermal efficiency may be expected to be at least 32 per cent. For the tunnel in question, therefore, total heat to be generated will be $\frac{11,900}{0.32}$, or 37,467 Btu per min. One gallon of fuel oil will yield about 148,000 Btu, and the burners must therefore consume $\frac{37,467 \times 60}{148,000}$, or about 15 gals of fuel oil per hour.

It will next be required to find the amount of generated heat carried by the air blown through the tunnel. Again consulting Table 2, it will be seen that the thermal efficiency of the heater selected is 80 to 90 per cent. Taking the lower value, the amount of generated heat carried by the air will be $0.80 \times 37,467$ or 29,974 Btu per min.

Now, in our present problem it has been found that 11,990 Btu per min will be absorbed from the air to meet the requirements for total heat of evaporation. Because heat will be lost through radiation, air leakage, and absorption in heating the tubers, trays, trucks, etc., a 10 per cent allowance should be made for the generated heat being carried by the air; 10 per cent of 29,974 is 2,997 Btu per min. Thus, the air passing through the tunnel will be required to furnish 11,990 (total heat of evaporation) plus 2,997, or 14,987 Btu per min.

The amount of generated heat carried by the air blown through the tunnel must be calculated. This is obtained from the specific heats of dry air and water vapor. At constant pressure, the specific heat of dry air is approximately 0.24; the specific heat of water vapor is 0.475. Then using the formula:

$$\frac{A}{B\ (C \times 0.24) + (D \times 0.475)}$$

we can obtain the volume of air required in cubic feet per min to give up a specified number of Btu per min. In the above formula

A = number of Btu required; in the present case this is 14,987.

B = temperature drop through the tunnel; this is 35° in the present problem.

C = lbs of dry air per cu ft. In the present problem it would be lbs dry air at a relative humidity of 20

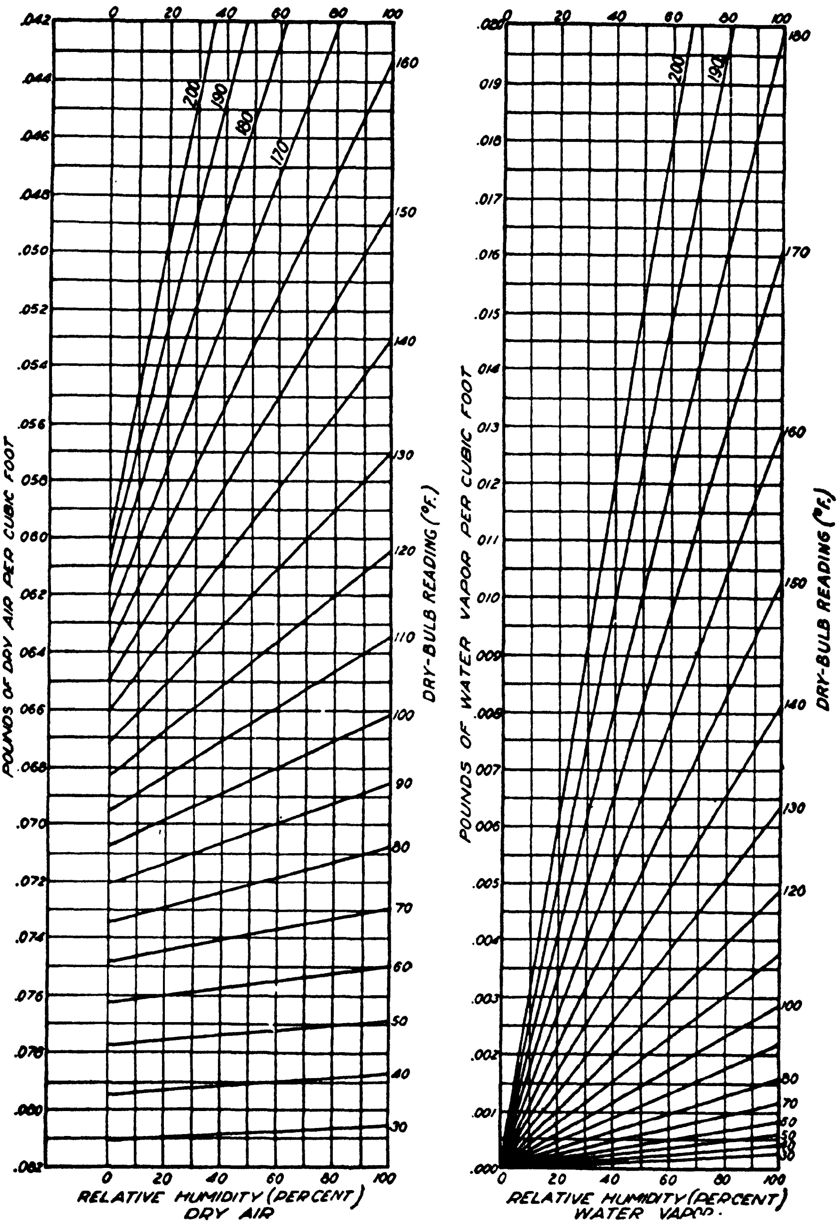


FIG. 10. Pounds of dry air and of water vapor per cubic foot, at a barometer reading of 29.921 (based on Table 1, p. 430, v. 1, of "Mechanical Equipment of Buildings," by Luis Allen Harding and Arthur Culls Willard, 1917). From Chace, Noel and Pease, "Preservation of Fruits and Vegetables by Dehydration," *U. S. Dept. of Agriculture Circ.* 619 (1942).

per cent and with a dry-bulb temperature of 150° F. (Fig. 10).

D = lbs water vapor per cu ft. In the present case it would be lbs of water vapor at a relative humidity of 20 per cent and with a dry-bulb temperature of 150° F. (Fig. 10).

Substituting in the formula:

$$\frac{14{,}987}{35^\circ(0.0618\times 0.24)+(0.0021\times 0.475)}=17{,}258$$

Since the tunnel has 26 1/9 sq ft of free cross-sectional area, the above volume of air blowing through the tunnel is $\frac{17{,}258}{26\ 1/9}$, or 643 linear ft per min.

To recapitulate: a tunnel, counter-current with recirculation designed to dry 10 tons of prepared potatoes per 24 hours under certain specified conditions would require:

11 trucks, each truck with 2 stacks of trays 3′×3′, 25 trays high and providing a total spreading area of 5000 sq. ft.
The free cross-sectional area of the tunnel will be 26 1/9 sq ft.
Quantity of water to be evaporated per min: 11 lbs.
Heat requirements: 37,467 Btu per min.
Fuel oil consumed: 15 gals per hr.
Amount of generated heat carried by air: 29,974 Btu per min.
Amount of heat given up by air: 14,987 Btu per min.
Velocity of air: 643 linear ft per min.

As stated above, these calculations are only approximate and should not be made an absolute basis for the construction of a tunnel dryer that would function with the maximum efficiency. The example is given merely to show the factors to be considered in the design of a tunnel dryer.

Factors Involved in Drying

Taking dehydraters as a whole, there are six important factors which determine the drying time of the material. These factors will be briefly discussed.

(1) **Design.** Any dehydrater which assures intimate mixing of rapidly moving air with the material being dried encourages rapid drying. The spray dryer perhaps meets this condition better than any other type. In the case of the tunnel dryer, rapid drying is best attained by moving the air through the tunnel in a direction opposite to that of the product; or by introducing hot air at both ends of the tunnel and exhausting the cool, moist air at or near the center. If air is forced through the material rather than over it, drying will be more rapid. Insulating the dryer against loss of heat, and eliminating air leakage favors rapid drying. Spray and tunnel dryers are rarely insulated, however. Cabinet dryers may be partly insulated. Rapid drying is favored by moving the air at high velocity. As previously mentioned, this velocity should not be less than 600 linear ft per min for vegetables, and preferably higher. For fruits a velocity lower than this is considered satisfactory. If the trays upon which the material is placed are made of metal, drying time will be considerably shortened.

(2) **Volume of Air Flow.** A high total volume of air flow is most suitable for rapid drying. But this is true only in the primary stage of drying. Sixteen thousand cu ft per min (cfm) of air flow will remove one pound of water for every 5° of temperature drop.

(3) **High Temperature.** If the incoming air is heated to the highest temperature consistent with safety for the particular material being dried, rapid drying will take place. The moist product will tolerate a higher temperature than the dried, as the material remains cool because of the rapid evaporation of water. At the beginning of the drying period, in the case of tunnel or cabinet dryers, the temperature of the moist product will be nearly that of the wet-bulb temperature, but as drying progresses, the temperature of the product will more nearly approach that of the dry bulb. (Fig. 11). A 15° wet-bulb depression is considered good practice.

(4) **Proportion of Recirculated Air.** If part of the air exhausted from a tunnel or cabinet dryer is returned and mixed with incoming fresh air and then reheated, the air passing over the product will become more moist than without such recirculation. The drying time will therefore be longer, but there will be a saving of heat. In drying vegetables in a cabinet or tunnel dryer, from 50 to 75 per cent of the air is recirculated. Theoretically, volume of

air flow, high temperature, and proportion of recirculated air will determine the maximum drying capacity of a cabinet or tunnel dryer. In actual practice, however, performance of these types of

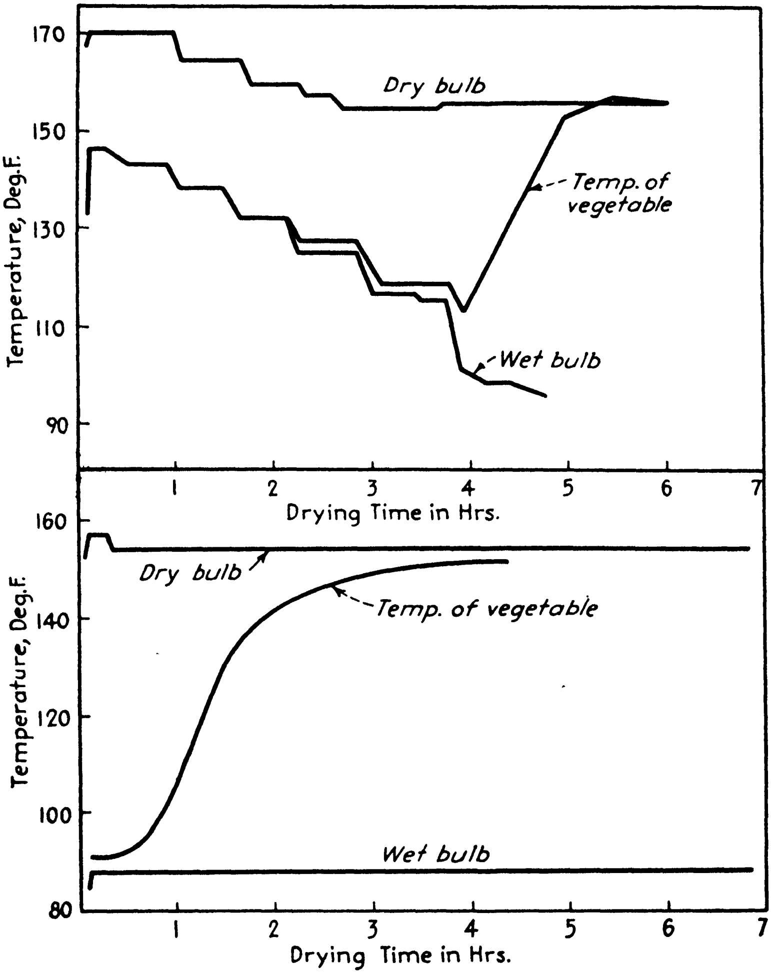


FIG. 11. Relationship between wet-bulb temperature and temperature of product being dehydrated in a cabinet dryer. Upper figure indicates dehydration with decreasing wet bulb; lower figure shows dehydration when wet bulb is constant. (Data from Dehydration Committee, Bur. Agr. Chem. & Eng., U. S. Dept. Agr.)

dehydraters will always be considerably less than this theoretical maximum.

(5) Rate of Input of Wet Product. In a cabinet or tunnel dehydrater, the ideal operation would be one in which the air

passing through the tunnel or cabinet would not cool, and would be low in relative humidity. This condition can be approached by decreasing the weight of moist material charged into the dryer. This decrease may be brought about by lighter loadings per sq ft of tray surface. A great many dehydrators have the tendency to over-load their trays, believing that in this way they can increase the capacity of their dryers. However, tray loadings can be heavier where the air is forced through the material than in the case where the air flows over the material. In one type of tunnel dryer, where the air is forced through the material, loadings are about 4 in deep at the start of the drying period, while at the end the loadings are increased to a thickness of about 11 in.

(6) Nature of the Product being Dried. If the moisture in the product to be dried is difficult to remove because of the physical structure or high sugar content, drying will not be rapid regardless of the amount of heat or air supplied. Thus, it requires much longer to dry uncooked meat than cooked meat in a tunnel or cabinet dryer, and it takes longer to dry young carrots than older carrots. In the case of meat, this is due to the difference in physical structure between raw and cooked; and in the case of carrots, the young vegetable contains more sugar than the old, the sugar present being hygroscopic and thus retarding drying time.

Table 3. Type of Dehydrater, Product Dried and Pounds of Steam Consumed Per Pound of Water Evaporated.

Type	Used for drying	Approx. lbs of steam consumed per lb of water evaporated
Cabinet	vegetables, fruit, meat, egg whites	2.0 to 3.0
Drum	milk, fruits and fruit juices, meat	1.6 to 2.0
Kiln	apples, potatoes	oil-heated
Rotary	alfalfa, citrus wastes	direct oil-fired
Spray	milk, whole eggs, egg yolks, fruit and vegetable juices, blood albumen	2 to 5[a]
Tunnel	meat, fruits, vegetables, egg white	2.25 to 3.0[b]
Vacuum (tray)	still experimental	1.2 to 2.0[c]
(pan)		1.3 to 1.8

[a] These may be heated by direct gas or oil.
[b] Usually heated by gas, indirect or direct oil.
[c] Claims have been made that this can be reduced to 0.916.

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Chapter 2

Sun-drying and Dehydration of Fruits

Fruits are either sun-dried or dehydrated in cabinet or tunnel dryers, but generally the latter. Methods of drying different fruits are given in Table 4. The percentages, where given, are only approximate. Practically all the sun-dried fruit, with the exception of bananas, is produced in California.

Table 4. Methods Used in Drying Fruits*

Sun-dried	Artificially dried
Prunes (30%);	Apples (100%);
Clingstone peaches (90%);	Prunes (70%);
Freestone peaches (90%);	Clingstone peaches (10%);
Apricots; Figs; Pears (95%);	Raisin grapes (35%);
Nectarines; Raisin grapes (65%);	Berries; Cherries; Bananas (95%);
Bananas (5%); Currants (100%).	Pears (5%).

*The percentages given under the different methods must be considered as only approximate.

In California, where the drying of fruits (with the exception of bananas) has become an important industry, the fruit is raised exclusively for that purpose, because a given variety may be suitable for fresh consumption or for canning and yet be unsatisfactory for drying. Table 5 gives the varieties of fruits generally considered satisfactory for drying.

Table 5. Varieties of the More Common Fruits Suitable for Drying

Apples	Gravenstein, Ben Davis, Stark, Baldwin, King, Wagener
Apricots	Royal, Blenheim, Tilton
Bananas	Gros Michel, Cavendish, Lady Finger, Plantain
Currants (Zante)	Black Corinth
Figs	Adriatic, Black Mission, Calimyrna, Kadota
Nectarines	Hardwick, Newboy, Quetta, Stanwick
Peaches (freestone)	Lovell, Muir, Elberta
Peaches (clingstone)	Phillips and California midsummer varieties
Prunes	French, Imperial, Sugar, Robe de Sergeant
Raisin grapes (unbleached)	Muscat, Sultana, Thompson Seedless
Raisin grapes (sulfur bleached)	Thompson Seedless
Raisin grapes (soda dipped)	Thompson Seedless.

In the case of prunes, sun-drying may be less expensive than

dehydration, but the yield is also less. Thus, Christie[1] in some of his investigations shows an average cost of $4.41 for dehydrating prunes, against $3.39 for sun-drying, these figures being on the basis of a green ton of fruit. The yield of sun-dried fruit was 969 lbs, while that of the dehydrated fruit was 1012 lbs per green ton, both yields figured back to the same moisture content. Christie points out, however, that these yields are startling and should not be accepted without further confirmation.

Apples

Except in isolated cases, apples are now never sun-dried, but dehydrated either by means of tunnel, drum or spray dryers or in kilns, depending upon the type of product desired. However, spray dryers are seldom used because the product obtained is a powder and of limited adaptability for general food purposes. Apple powder has found its greatest outlet in therapeutics where it is recommended as a corrective in certain diarrheal conditions of infants.

Varieties for Dehydration. Gravenstein, Ben Davis, Stark, Baldwin, King, Yellow Newtown Pippin, Esopus (Spitzenberg) and Wagener are the most suitable for dehydration. Other varieties may be used, but the yield of dried product in some cases is lower than when the varieties named above are utilized.

Size of Apples. If small apples are used, there will be more handling per unit weight than in the case of large sizes. Waste also will be greater with the smaller sizes. In general, therefore, it is not economical to use fruit under 2¼ inches in diameter.[2,3] Warehouse culls are also considered unsatisfactory because they are quite often of small-size. It is deemed uneconomical to pare deformed, badly bruised or unsound fruit.

Storage of Fruit. If fruit is to be held for any length of time prior to dehydration, and in many cases this is necessary, it should be stored in covered bins with a slatted floor; and to prevent bruising, the apples should not be piled in the bins to a depth of more

[1] Christie, A. W., "Successful Dehydration," *Pacific Rural Press*, p. 589 (Nov. 25, 1922).

[2] Anon., "Dehydration of Fruits and Vegetables in Canada," *Nova Scotia Dept. Agr. Dominion of Canada.* Bul. 90.

[3] Eidt, C. C., "Principles and Methods Involved in Dehydration of Apples," *Dominion of Canada. Dept. Agr.* Bul. 18 (1938).

than 4 or 5 feet. The bins should be constructed in a cool place and provided with adequate ventilation so that the fruit can be maintained at as low a temperature as possible without freezing.

Washing. The apples must first be washed to remove grit and dirt. Since they are subsequently peeled, it is not necessary to give them an acid wash to remove spray residue unless the waste is to be used for feed or other purposes. If the peel is to be dried for pectin or feed manufacture, and the fruit has been sprayed, it will be necessary to acid treat before peeling. This may be carried out by immersing the apples for about 3 min in a 0.5 to 1.0 per cent solution of hydrochloric acid at 70° F. If power-spray washing machines are used, a 30-second treatment may be sufficient. A solution of hydrochloric acid of approximately 0.5 per cent can be made by adding 1½ gals of concentrated acid to each 100 gals of water. After the acid treatment, the fruit must be washed with clean water to remove the acid.

There is some question as to the economic feasibility of acid-treating fruit and drying the peel for pectin manufacturers. Normally, the price of dried peel is about $0.01 per pound and it is doubtful that the peel could be acid washed and dried for this price. The peel cannot be dried without acid treatment because the arsenic and/or lead content of the finished product would exceed the Federal tolerance.*

The acid-washed peel may be dried to about 8 per cent moisture in steam-heated rotary dryers at a temperature of about 160° F. Most manufacturers believe that a superior product is obtained by kiln-drying.

Peeling and Coring. This is done by machine, the peeling and coring being accomplished in one operation. Peeling should be thorough because subsequent grading of the dried product will be governed to some extent by the presence of peel. The peel will not rehydrate as well as the pulpy part of the fruit and apples with peel will be tough when rehydrated.

Peeling and Trimming Loss will amount to from 25 to 35 per cent.

Slicing or Dicing. The peeled, trimmed fruit may be sliced into rings ¼ in thick, or diced in ¼-in cubes.

* Not more than 0.05 grain of lead per pound, nor more than 0.025 grain of arsenic (as arsenic trioxide) per pound. McNutt, P. V., "Notice to Growers and Shippers of Apples and Pears," (Aug. 10, 1940).

Sulfuring. Apples must be sulfured before drying because freshly cut apple tissue quickly darkens due to the presence of the enzyme catalase. The cut fruit should be kept immersed in dilute (1 per cent) brine until ready for sulfuring.

Sulfuring may be carried out by placing the slices or dices in sulfuring houses (p. 46), or by immersing in a dilute solution of sulfurous acid or a sulfite (1 to 3%, as sulfurous acid). Sulfur dioxide may also be used in place of burning sulfur. If burning

Courtesy U. S. Dept. of Agriculture. (Photograph by Knell)

FIG. 12. Kiln drying of apples. Slices of apples are spread in a shallow layer over the latticed floor of the drying chamber on the second floor of a Niagara County, N. Y., evaporating plant. Heat rising from kilns below the lattice dries the apple slices. Sulfur dioxide introduced into the chamber bleaches them. After exposure for 48 hours to a temperature of 100° F. and the burning sulfur fumes, the dried apples will be bagged for shipment. Millions of bushels of apples harvested in 1943 will be dried, largely for our fighting forces and our allies, and also for commercial pie makers.

sulfur is used—the most common method—rings are exposed for 30 min; dices for 15 min. About 7 lbs of sulfur per ton of fruit is generally sufficient.

Dehydration. After sulfuring, the material is ready for dehydration. This is preferably accomplished in a tunnel dryer, and the trays are loaded at a rate not exceeding 1.5 lbs per sq ft of drying area. The drying temperature at no time should exceed 160° F. It is

necessary to avoid high humidities during drying, otherwise discoloration will result. A relative humidity of from 20 to 30 is considered preferable. Drying time will vary from 6 to 10 hours.

Resulfuring. During drying, most of the sulfur will be lost from the fruit. In the case of some fruit, discoloration will occur after drying. Eidt[3] states that the rate of discoloration is affected by exposure to light, by heat, and by the moisture content of the dried fruit. Best results in resulfuring are obtained if the apples contain around 25 per cent moisture. If the fruit is too dry, it can be dampened and placed in bins to equalize the moisture content, but the fruit should not be piled deeper than 4 feet in such bins. It requires about a week to equalize the moisture in this manner. The apples are then resulfured by exposing to fumes of burning sulfur for about 20 min. The finished product should not contain less than 500 ppm (parts per million) nor more than 2000 ppm of sulfur dioxide. Darkening will result if the fruit contains less than 500 ppm of sulfur dioxide.

Moisture content of the finished product should not exceed 24 per cent.

Yield will vary according to the variety of apple and locality in which grown. In general, the yield will be from 14 to 17 per cent, based on the weight of the fresh, unprepared fruit.

Screening. Before grading and packing, it is necessary to screen the dehydrated product to remove chips, seeds and seed vessels (carpels). A slowly rotating screen with a one-inch mesh is satisfactory. The chips obtained may be screened again through a $\frac{5}{8}$-inch mesh screen to remove seeds and carpels.

Grading. Dried apples are sold as rings, which are segments of apples obtained by slicing whole apples at right angles to the core; quartered, *i.e.*, segments of apples obtained by cutting the whole fruit longitudinally into three, four or six approximately equal units; and sliced, *i.e.*, segments obtained by cutting whole apples longitudinally into eight or more approximately equal units. These different types are divided into the following grades, according to the Agricultural Marketing Administration of the U. S. Department of Agriculture.

U. S. Grade A or U. S. Fancy. Dried apples of this class possess a bright, light yellow to white color. Not more than 20 per cent by weight may be damaged by cores; not more than 10 per cent by

weight may be damaged by bad bruises, pieces of skin, bitter pit or other corky tissue, disease, worm holes, insect injury, or other similar defects; and not more than 5 per cent by weight of the pieces may be affected by mold, insect infestation, decay, or other foreign material, or may be damaged by calyxes, stems, or dirt, of which not more than one-tenth (or 0.5 per cent by weight of the total fruit) may be affected by decay. The total of all defects, except damage by cores, within the limits prescribed above, shall not exceed 10 per cent by weight. In addition, the following requirements are applicable to the various styles:

Rings. Not less than 60 per cent by weight shall be whole or practically whole rings and not more than 5 per cent by weight may be so small as to pass readily through a $\frac{5}{8}$-inch square mesh screen.

Quartered. Not less than 95 per cent by weight shall be whole or practically whole quarters and not more than 2 per cent by weight may be so small as to pass readily through a $\frac{5}{8}$-inch square-mesh screen.

Slices. Not less than 80 per cent by weight shall be whole or practically whole slices.

U. S. Grade B or U. S. Choice dried apples possess a reasonably bright, yellow to white color. Not more than 30 per cent by weight may be damaged by cores; not more than 15 per cent by weight may be damaged by bad bruises, pieces of skin, bitter pit or other corky tissue, disease, worm holes, insect injury, or other similar defects; and not more than 6 per cent by weight of the pieces may be affected by mold, insect infestation, decay, or other foreign material, or may be damaged by calyxes, stems, or dirt, of which not more than one-twelfth (or 0.5 per cent by weight of the total fruit) may be affected by decay. The total of all defects except damage by cores, within the limits prescribed above, shall not exceed 15 per cent by weight. In addition, the following requirements are applicable to the various styles:

Rings. Not less than 50 per cent by weight shall be whole or practically whole rings and not more than 5 per cent by weight may be so small as to pass readily through a $\frac{5}{8}$-inch square-mesh screen.

Quartered. Not less than 90 per cent by weight shall be whole

or practically whole quarters and not more than 3 per cent by weight may be so small as to pass readily through a $\frac{5}{8}$-inch square-mesh screen.

Sliced. Not less than 65 per cent by weight shall be whole or practically whole slices.

U. S. Grade C or U. S. Standard dried apples possess a fairly bright, yellow to white color. Not more than 40 per cent by weight may be damaged by cores; not more than 20 per cent by weight may be affected by pieces damaged by bad bruises, pieces of skin, bitter pit or other corky tissue, disease, worm holes, insect injury, or other similar defects; and not more than 8 per cent by weight of the pieces may be affected by mold, insect infestation, decay, or other foreign material, or may be damaged by calyxes, stems, or dirt, of which not more than one-sixteenth (or 0.5 per cent by weight of the total fruit) may be affected by decay. The total of all defects, except damage by cores, within the limits prescribed above, shall not exceed 20 per cent by weight. In addition, the following requirements are applicable to the various styles:

Rings. Not less than 30 per cent by weight shall be whole or practically whole rings and not more than 10 per cent by weight may be so small as to pass readily through a $\frac{5}{8}$-inch square-mesh screen.

Quartered. Not less than 85 per cent by weight shall be whole or practically whole quarters and not more than 4 per cent by weight may be so small as to pass readily through a $\frac{5}{8}$-inch square-mesh screen.

Sliced. Not less than 50 per cent by weight shall be whole or practically whole slices.

Off-Grade dried apples are wholesome and edible dried apples that fail to meet the requirements of the U. S. Grade C or U. S. Standard.

Apple Nuggets

These are prepared by quickly cooking dehydrated apples and then dehydrating in vacuum dryers.[4] The process puffs the material until it is quite light and porous. Apple nuggets contain about 3 per cent moisture.

[4] Cruess, W. V., "Dehydration of Fruits and Vegetables," *Ind. Eng. Chem.*, **35**, **53** (1943).

Apple Powder

Apple powder may be produced by spray drying a slurry of peeled apples, or the apples prepared as already described may be vacuum-dried, ground and bolted. Production of apple powder is not as great as of apple rings because the former is a specialty product with limited use. The approximate composition of an apple powder, and apple rings is given in Table 6.

Table 6. Approximate Composition of an Apple Powder and Apple Rings

	Apple powder[a]	Apple rings[b]
Moisture (%)	2.0	23.0
Total solids (%)	98.0	—
Ash (%)	1.8	3.5
Fat (ether extract) (%)	2.5	0.4
Protein (N x 6.25) (%)	1.5	5.2
Crude fiber (%)	6.7	3.2
Reducing sugars (%)	52.0	46.0
Sucrose (%)	17.1	
Pectin (%)	5.2	—
Uronic acids (%)	9.2	—
Total carbohydrates (%)	84.1	—
Total acid as malic (%)	2.9	5.0
pH	3.5	—
Undetermined (%)	—	13.7

[a] Manufacturer's analysis.
[b] Modified from Chatfield and Adams, *U. S. Dept. Agr. Circ.* 549 (1940).

Apricots

Apricots are sun-dried in California in the Santa Clara, Sacramento and San Joaquin Valleys. The drying season extends from about June 15 to August 1st.

Varieties for Drying. Royal, Blenheim, Tilton are used, and these should be harvested when they are somewhat riper than desired for canning purposes.

Washing. The fruit is not always washed, but washing is recommended and this should be done before cutting. Washing is usually by means of a continuous washer in which the fruit is carried on an endless belt between water sprays.

Peeling. Apricots are not peeled before drying.

Cutting. From the washers, the fruit is taken to the cutting sheds, which generally consist of a roof with supporting posts but no sides. This type of shed affords protection of the workers from the hot sun and gives adequate ventilation. Metal roofs are not

desirable because they radiate too much heat. In some instances the roof is constructed of slats which prevent sun glare but do not keep out the light. Protection against rain is not necessary because the fruit is not handled during the rainy season. The floor of the shed is usually well-trampled earth, which is considered more comfortable for the workers than a concrete floor.

The cutting tables are of standard design and made in sections about 30 in high, 8 ft long and 3 ft wide. Each section will provide space for 8 cutters. Work plans for such a table may be obtained from the Agricultural Extension Service, University of California, Berkeley, California.

Courtesy E. M. Chace, U.S.D.A.

FIG. 13. California Packing Corp. drying yards at Tuttle, Calif. Peach and apricot sulfuring houses in background.

A sharp knife is used and the fruit is cut completely around the suture. The fruit is then separated and the pit removed. If the apricot is not completely cut through and then torn apart, the halves may flatten out during drying and "slabs" will result. Slabs bring a lower price than clean halves.

The cutters are paid on the number of boxes of 'cots cut each day; one experienced girl can cut about 1000 pounds of fruit per day.

Sulfuring. The cut fruit is placed, cup side up, on wooden trays at the rate of about 2 lbs per sq ft of tray surface. The trays are usually 3′×6′ and constructed of pine or redwood, the bottom consisting of boards about 5¾″ wide and ¼″ thick. It is necessary to have the trays of sufficiently rigid construction to withstand the weight of the fruit, for each tray will contain about 36 pounds of

fruit. Mrak and Long[5] state that the following material is necessary for one $3' \times 6'$ tray:

end cleats 2 pcs. $1\frac{3}{8}'' \times 1\frac{3}{4}'' \times 34\frac{1}{4}''$
side cleats 2 pcs. $\frac{7}{8}'' \times 1\frac{3}{4}'' \times 6'$
clinch cleats 3 pcs. $\frac{3}{8}'' \times 1\frac{1}{4}'' \times 6'$
bottom boards 12 pcs. $\frac{1}{4}'' \times 5\frac{3}{4}'' \times 3'$

According to these authorities, total cost for each tray amounts to $0.50. It should be remembered, however, that these cost figures were under conditions prior to World War II, and under present economic conditions the cost will be much greater.

The trays containing the cut fruit are now stacked on trucks similar to those used in the drying of vegetables. The trays are staggered in loading on the trucks and every other tray overhangs about 6 inches. This is for ease in handling and for better circulation of sulfur dioxide fumes during sulfuring. It is desirable to sulfur the fruit as soon as possible after cutting to prevent darkening, and to preserve vitamin C (p. 216).

The loaded trucks are pushed on tracks into sulfuring houses. These are rather simple in construction (Fig. 13), and to decrease fire hazard they are usually set up as two or more separate structures rather than as one large building, so that if a fire results damage will be kept to a minimum. It is important that sufficient vents be provided in these houses to obtain complete combustion. Generally, about one square inch of vent area to every 50 sq in of burner surface is considered advisable. The ratio holds, however, only when a 10-in pan is used for burning the sulfur.

The sulfur is burned in clean, metal pans; a tin pan 10 in in diameter and about 3 in deep is considered satisfactory for a sulfuring house holding a single car (1000 lbs fruit). A good grade of sulfur should be used, and at the rate of 3 to 4 lbs per ton of fruit to be sulfured. Even extremely small amounts of certain impurities will prevent complete combustion of the sulfur. The researches of Bisson, *et al.*[6] have shown, for instance, that the presence of only a few parts per million of oil will retard complete burning of sulfur. Therefore sulfur should not be stored in garages

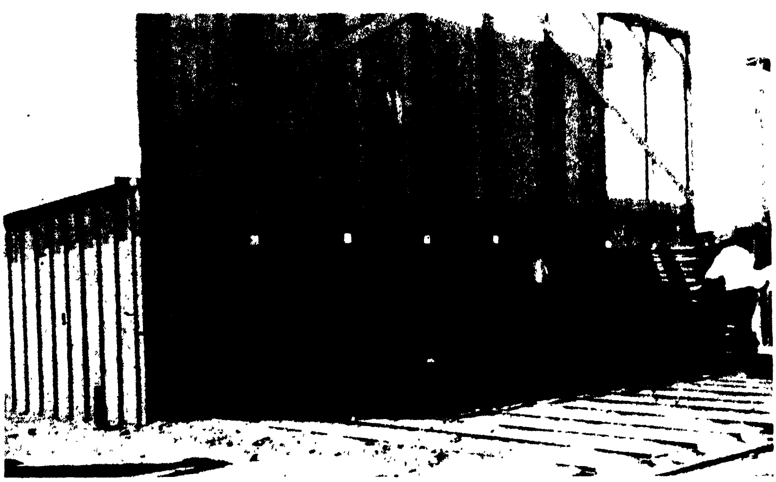
[5] Mrak, E. M., and Long, J. D., "Methods and Equipment for the Sun-Drying of Fruits," *Univ. Calif. Agr. Expt. Sta. Circ.* 350 (Nov., 1941).

[6] Bisson, C. S., Allinger, H. W., and Young, H. A., "Some Factors Affecting the Burning of Sulfur used in Sulfuring Fruits," *Hilgardia*, 14, No. 6, 361 (1942).

Table 7. Effect of Temperature and Time of Sulfuring on Sulfur Dioxide Absorption and Retention by Apricots
(*After Fisher, Mrak and Long*)

Temp. during sulfuring (°F)	sulfuring period (min)	SO_2 absorbed during sulfuring (ppm)	SO_2 retained after drying (ppm)
	Royal apricots at Aromas (1939)		
	40	1730	200
	80	2560	300
62°	120	2970	170
	160	3430	310
	200	3870	300
	40	1110	210
	80	1860	310
78°	120	2780	390
	160	3180	330
	200	3340	440
	40	1620	410
	80	2020	650
117°	120	2300	800
	160	2510	700
	200	2970	860
	Royal apricots at Aromas (1940)		
	40	1610	120
	80	2570	230
66°	120	2920	260
	160	3500	230
	200	3570	310
	40	2070	220
	80	2880	280
93°	120	3040	380
	160	3530	330
	200	3340	510
	40	1380	260
	80	1870	310
117°	120	2240	390
	160	2600	560
	200	2750	600
	Tilton apricots at Fresno (1939)		
	40	2280	1790
	80	3540	2450
66°	120	4390	2270
	160	6190	3510
	200	6200	3690
	40	1960	1840
	80	2430	2090
93°	120	3360	2860
	160	4010	3130
	200	3940	3590
	40	2050	1820
	80	2730	2890
122°	120	3150	4140
	160	3750	4090
	200	3970	5090

or near trucks or automobiles. Two to three hours of sulfuring are deemed sufficient, and the finished dried product should contain at least 2000 ppm, but not more than 2500 ppm of sulfur dioxide. If not properly sulfured, the fruit will turn brown during or after drying. Fisher, Mrak and Long[7] have shown that apricots as a rule absorb less sulfur dioxide during sulfuring, but retain more after drying, when sulfured at 120° F. However, the extent of the temperature effect was found to vary considerably with the length of the sulfuring period, nature of the fruit, and the locality in which it is dried. Prolonged high-temperature sulfuring periods tend to cause the fruit to bleed, become mushy and stick to the drying trays.



Courtesy E. M. Chace, U.S.D.A.

FIG. 14. Apricot sulfuring houses.

The only certain criterion of adequate sulfuring is a measurement of the amount of sulfur dioxide in the dried fruit (p. 259).

Drying. The sulfured fruit should be taken to the drying yard as soon as possible after sulfuring. If the fruit is allowed to remain in the sulfuring house, juice may accumulate in the cups, and will very likely spill during subsequent handling, soil the trays and decrease the yield and quality of the dried product.

[7] Fisher, C. D., Mrak, E. M., and Long, J. D., "Effect of Time and Temperature of Sulfuring on Absorption and Retention of Sulfur Dioxide by Fruits," *Fruit Prod. J.*, 21, 175; 199; 219; 237 (1942).

The drying yard is generally located quite near the cutting sheds, and the site is selected so that the trays will be exposed to the prevailing winds. Ground with a gentle slope is considered advantageous; the earth should not be dusty, and it is preferably covered with a stubble growth of hay or grain to keep down the dust.

The size of the dry yard will vary according to the production of dried product. In general, it will require about 1 acre of dry yard for each 20 acres of orchard, but this ratio may vary considerably. In small yards, transportation of the trays from the sulfur house to the dry yard is done by hand. But in large yards, it is necessary to have a system of tracks. These tracks are usually 10- or 12-pound rails spiked to wood ties (treated with creosote to retard decay) or welded to steel angle ties. Track gauge for tray cars is 2 feet; that for transfer cars, 4 feet.

The trays in the dry yard may be placed on racks raised about a foot from the ground, or on wooden horses. The fruit is exposed to the sun for from 1 to 7 days, depending upon the climate. The dried fruit should contain about 18 per cent moisture and should be soft and pliable, but not sticky.

Curing. All the dried apricots on the trays will not be of the same moisture content and it is therefore necessary to equalize this moisture. The fruit is scraped from the trays with wooden or metal scrapers, care being taken to avoid incorporating dirty, discolored or insect-infested fruit, or splinters. During this operation the fruit is also sorted and slabs removed. Very wet fruit is returned to the trays for further drying, while the properly dried fruit is placed in lug boxes or sacks to be transported to the curing or "sweating" bins. Here the fruit is allowed to remain for one to three weeks, during which time some moisture is transferred from the wetter pieces to the drier ones.

Yield. The yield will vary from 15 to 20 per cent, based on the weight of the fresh, unprepared fruit.

Grading. The apricots are graded before packing because they are then easier to handle. There are six grades of apricots according to California practice (Table 8). Tentative grades according to the Agricultural Marketing Administration U. S. Department of Agriculture are given in Table 9.

Table 8. Grading Sizes for Dried Apricots
(After Mrak and Long)

Grades	Screen sizes for "Santa Clara" apricots (in.)	Screen sizes for "San Joaquin" apricots (in.)
Standard	28/32	28/32
Choice	32/32	32/32
Extra fancy	36/32	38/32
Fancy	40/32	42/32
Extra fancy, Blenheims & Fancy Moorpacks	44/32	over 42/32
Extra fancy Moorpacks	46/32	—

Table 9. Tentative Standards of Grades for Dried Apricots
(Agr. Market. Admin.)

Grade	Diameter (in.)
No. 1 (Extra Fancy)	$1\frac{1}{4}$ or larger
No. 2 (Fancy)	$1\frac{1}{8}$ to $1\frac{1}{4}$
No. 3 (Extra Choice)	1 to $1\frac{1}{8}$
No. 4 (Choice)	13/16 to 1
No. 5 (Standard)	less than 13/16

Before grading and processing it should be ascertained that the fruit is free from insect infestation, mold and dirt.

Processing. The graded fruit is passed over a shaking screen and then through a cleaning machine consisting of a wire cylinder with rubber-tipped paddles. Water is sprayed into the cylinder for the purpose of cleaning the fruit, and moistening it to facilitate better absorption of sulfur dioxide in subsequent sulfuring. The washing operation also renders the fruit more pliable. About 10 to 12 per cent moisture is absorbed during this operation.

Sulfuring. The washed fruit is spread on the trays, which are staggered as in the first sulfuring operation, to a depth of about 2 or 3 inches, and then returned to the sulfuring houses. Here they are exposed again to the fumes of burning sulfur for about 4 hours.

Moisture content of the finished product will generally run from 20 to 25 per cent.

Dehydration of Apricots

The fruit is prepared in the same manner as for sun-drying. The halved fruit should be steamed for 2 to 4 min before sulfuring. One hour of sulfuring is considered sufficient as against 2 to 3 hours if the fruit is sun-dried.

Tunnel dryers are used at a temperature not exceeding 150° F. At the start of the drying it is necessary to use rather high rela-

tive humidities (50 to 55 per cent) to prevent case-hardening. Drying time is from 15 to 20 hours under these conditions.

After drying, the fruit is not resulfured, but is ready for grading and packing. When ready for packing, the moisture content will vary from 15 to 20 per cent.

Utilization of Apricot Pits. Apricot pits are of commercial value in that they are used for cookie fillers, activated carbon and chemicals. The pits are collected in the dry yard in clean containers, care being taken not to mix them with trimmings and discarded fruit. The pits are then dried by spreading on trays or on a clean concrete floor. They must be stirred periodically to encourage uniform drying. Apricot pits should not be sulfured because sulfured pits have no commercial value.

The dried pits are crushed between iron rollers to break the pits and release the kernels. The fractured pits are placed in a tank of brine to separate the kernels from the pits, the kernels floating while the pits sink to the bottom. The separated kernels are sprayed with water to remove salt, dried and then sorted to remove defective material. From 23 to 24 per cent kernels are obtained.

The kernels are the most valuable, and from them is obtained a fatty oil and benzaldehyde. The former is extracted either by an expeller or by hydraulic presses, the yield of crude oil amounting to about 30 per cent. The crude oil is dark in color and possesses a rancid taste. It is refined by treatment with an alkali and bone char, yielding a bland-tasting product which may be used as a salad oil.

The press cake from the fatty oil contains amygdalin and emulsin, the latter an enzyme which will convert amygdalin into benzaldehyde, glucose and hydrocyanic acid. To bring about this conversion, the press cake is heated to 122° F for about an hour with 12 volumes of water. The mixture is then steam-distilled, yielding benzaldehyde and hydrocyanic acid. If the oil is to be used for food purposes, the hydrocyanic acid must be removed. This is accomplished by heating with slaked lime and an iron salt, or by treatment with sodium bisulfite. The benzaldehyde is then redistilled. The yield will amount to about 2 per cent, based on the weight of the press cake.

The cake, after removal of benzaldehyde, may be pressed to remove excess water, and used as a cattle feed.

The pits of the apricot, left after removing the kernels, may be destructively distilled in the same manner as wood, yielding acetone, methyl alcohol, acetic acid, tar and a residue of charcoal.

Kernels may also be used in preparing macaroon paste, by blanching to loosen the skins, grinding and then heating at about 122° F to hydrolyze amygdalin, steam-distilling to remove benzaldehyde and hydrocyanic acid, and then pressing. The residue is then mixed with sucrose and heated in steam-jacketed kettles.

Dried apricots have essentially the following composition (modified from Chatfield and Adams):

Water (%)	24.0
Protein (N x 6.26) (%)	5.2
Fat (ether extract) (%)	0.4
Ash (%)	3.5
Total sugars (%)	46.0
Crude fiber (%)	3.2
Total acid, as malic (%)	5.0
Undetermined (%)	12.7
	100.0

BANANAS

This fruit is either sun-dried, spray- or drum-dried. All the sun-dried fruit is prepared in the tropics. Spray- and drum-dried fruit has limited use in that it is sold in the form of a powder. Most of the banana powder produced is drum-dried because entrainment and wall losses in spray drying are too great. Banana powder may be mixed with chocolate or cocoa and dried milk to prepare a beverage. Ripe banana powder finds use in therapeutics in the treatment of celiac disease, sprue and other forms of carbohydrate intolerance of this nature. It may also be used in the adult diet for the treatment of certain intestinal disturbances. Banana flour is prepared from green (unripe) fruit or from Plantains which contain large percentages of starch.

Varieties. The Gros Michel, Cavendish, Lady Finger and Plantain are used. The Lady Finger usually has a hard core and is not as suitable as the other varieties named.

Spray Drying. The following description of spray drying deals with one type of dryer that has been used commercially. The fruit is first peeled * and then passed through a meat chopper. If a light-colored product is desired, the peeled fruit should be dipped in a

* Green fruit is difficult to peel and must first be immersed in hot (186° F) water for four or five minutes. Peeling loss will amount to from 45-57 per cent.

1 or 2 per cent solution of a sulfite before grinding. The slurry formed by grinding is pumped into storage tanks. From the storage tanks, the material is run through a colloid mill which grinds the slurry to a very fine consistency. The material is then pumped, by means of a variable-speed pump, to a turbine-driven atomizer located at the top of the drying tower.

FIG. 15. A bunch of bananas ready for harvesting. The terminal flower bud (spathe) is shown developed below the bunch. This bud is composed of maroon-colored bracts and clusters of creamy-white, yellow-tipped male flowers (from a photograph).

The drying tower may consist of a large cylinder 20 to 25 ft in diameter and 25 to 30 ft in height. It may be constructed of hollow tile or heavy sheet iron. There seems to be little necessity of stainless steel construction because the material to be dried has a pH of about 5.4 and there is little corrosion of metal.

Hot air, which may come from an oil burner, is admitted near the top of the tower through a duct. In the case of the tower described above, this duct would have a cross-section area of about 4 sq ft. The air is sucked into the tower and then exhausted through suitable ducts about 5 ft above the bottom of the tower. The cross-section of these exhaust ducts should be such that the exhaust air is of low velocity. This is necessary to reduce the amount of powder lost by entrainment.

The atomized slurry meeting the hot air is dried and falls to the bottom of the dryer. The air in the dryer in contact with the dried product is maintained at 85-90° F and with a relative humidity not exceeding 30 per cent.

A spray dryer of approximately the size mentioned above should produce from 100 to 150 pounds of powder per hour.

In the spray drying of bananas there are two major types of losses: wall losses and entrainment losses. The former is caused by poor atomizing, in which the material is thrown against the walls of the dryer, where it sticks and becomes charred. The latter is caused by the powder being carried through the exhaust ducts; it may be diminished by decreasing the velocity of the exhausted air and by the installation of efficient dust collectors. Dust collectors, however, when they become heavily loaded, increase the static pressure within the drying chamber, and means must be provided to clear the collectors.

Table 10. Analyses of Dried Bananas

	Banana flour made from green fruit[a]	Banana powder made from full yellow fruit[b]	Banana powder made from ripe fruit[a]
Water (%)	5.99	3.80	2.59
Protein (N x 6.25) (%)	3.87	4.18	4.09
Fat (ether extract) (%)	1.06	2.01	1.91
Starch (%)	65.61	29.87	29.87
Reducing sugars (as invert) (%)	8.30	17.72	15.62
Non-reducing sugars (as sucrose) (%)	0.64	26.83	33.25
Ash (%)	3.06	3.07	3.05
Undetermined (tannins, crude fiber, etc.) (%)	11.47	12.52	9.62

[a] von Loesecke [b] manufacturer's analysis.

Yields in spray drying range from 8 to 11 per cent based on the weight of the fresh, unprepared fruit cut from the stem.

Drum Drying. This is the preferred method of preparing banana powder because all the solids are recovered. The ground pulp is fed as a thick film to the steam-heated drums. The distance

between the drums must be carefully adjusted to correspond to variations in the ripeness of the fruit. If they are not properly adjusted, the product may come off the drums as a sticky mass, or it may be too crumbly.

Yields in drum drying average about 13 per cent, based on the weight of the fresh, unprepared fruit cut from the stem.

Moisture content of a satisfactory banana powder will vary from 3 to 6 per cent.

Sun-drying of Bananas. This method is carried out by the natives in those countries where the fruit is raised. The fruit is peeled and then cut into small pieces, or split along the longitudinal axis. Knives made of bamboo or some non-ferrous metal are used for cutting, to prevent discoloration. The cut pieces are placed on trays and allowed to remain in the sun for one or two days until the final moisture content is approximately 15 per cent. The dried fruit may be put into a mortar, pounded until broken up and then sifted. Or it may be left in its original shape, in which case it is a dark, leathery looking material and usually has a "cooked" banana taste (commonly called "banana figs").

Cabinet Drying. This method is not being used commercially in the United States at present, but it has possibilities, especially under present war conditions, where shipping space for fresh fruit from the tropics is difficult to obtain. Ripe bananas are used; after peeling, the fruit is cut along the longitudinal axis and the halves immediately sulfured by dipping in a 3 per cent solution of sulfurous acid. The sulfured fruit is then spread on trays and dried at 150-160° F; drying time is from 8 to 10 hours. The yield amounts to about 12 per cent, based on the weight of the fresh, stemmed fruit. The finished product, when sulfured as above, will contain about 130 ppm of sulfur dioxide.

At present, there appears to be little market for this product.

Cherries

These are not dried commercially to any great extent.

Varieties. Royal Anne and Biggareau (Black Tartarian), Early Richmond and Montmorency are used.

Preparation. The harvested fruit is sorted and then stemmed by hand. It is not advisable to stem the fruit unless it is to be dried immediately. Stemming damages the cherries to some extent and

allows access of microörganisms which will start decay. The stemmed fruit is washed in tanks of cold, clean running water or by sprays of clean water.

The fruit may be dried pitted or unpitted. If pitted, this is accomplished by machines especially designed for the purpose. There is considerable loss of juice during pitting.

Cruess [8] recommends dipping the cherries in a 0.25 to 0.5 per cent lye solution before drying, and in the case of white or pink cherries sulfuring for about 15 min. Chace *et al.*[9] advocate steaming the fruit for about 2 min. Pitted cherries are said to require no sulfuring. There is some doubt whether cherries need to be lye-treated or sulfured if artificially dried.

Loss in Preparation. In unpitted cherries, preparation losses run from 1 to 3 per cent; in pitted cherries, from 17 to 23 per cent.

Traying. The fruit, prepared as described above, is loaded on the drying trays at the rate of about 1 lb per sq ft of drying surface. The trays used are similar to those already described (p. 46).

Drying Conditions. Maximum drying temperatures should not exceed 165° F and the relative humidity at the end of the drying period should be between 10 and 25 per cent, preferably the former. Under these conditions, in a counter-current dryer, drying time will be from 8 to 12 hours.

Moisture content of the dried product should not exceed 20 per cent and should preferably be about 15 per cent.

Yield. This will vary from 18 to 24 per cent in the case of pitted cherries, and from 24 to 30 per cent in the case of unpitted fruit, based on the weight of the fresh, unprepared material.

Cranberries

These are most often dried on drum dryers and dispensed in the form of flakes, although they can be dried in tunnel or cabinet dryers. In the latter case, the material is dried in the form of chopped pieces, although they can be dried whole.

Preparation. If drum-dried, the ripe berries are prepared in essentially the same manner as for canning, *i.e.*, they are passed

[8] Cruess, W. V., "Commercial Fruit and Vegetable Products," 2nd Ed., McGraw-Hill Book Co., 1938.

[9] Chace, E. M., Noel, W. A., and Pease, V. A., "Preservation of Fruits and Vegetables by Commercial Dehydration," *U. S. Dept. Agr. Circ.* 619 (1942).

through a separator to remove chaff, leaves and other debris and the cleaned fruit then washed and graded. To every 300 lbs of berries is added 25 lbs of water; the mixture is then heated to 180° F and passed through a finisher. The pulped berries are drum-dried, which requires about 2 or 3 min. The product obtained is in the form of flakes and should not contain more than 5 per cent moisture.

Yield. One hundred pounds of berries will yield about 10 lbs of dried flakes.

Tunnel or Cabinet Drying. The berries, cleaned as described above may be chopped into pieces or left whole. They may or may not be steamed for about 2 min, but steaming is preferable.

Tray loading is at the rate of about 0.8 lb per sq ft, and drying temperatures should not exceed 150° F.

Drying time is from 5 to 10 hours.

Final moisture content of the product should be about 5 per cent.

Figs

Figs are nearly always sun-dried, the processing being carried out chiefly in the San Joaquin Valley in California from about July 20 to November 1.

Varieties. The Adriatic, Black Mission, Calimyrna and Kadota are considered suitable for drying. However, only a limited quantity of Kadotas is dried; this variety is the only one used for canning.

Harvesting. The fruit is allowed to remain on the trees until ripe enough to fall to the ground. If immature figs are picked, the dried fruit gives a woody product of poor flavor. After falling to the ground, the fruit is promptly gathered because there is danger of insect infestation.

Fumigation. After harvesting, the figs, with the exception of the Kadota, should be immediately fumigated. The purpose of fumigation is to protect the fruit from the raisin moth, *Ephestia figulilella* Greg., and particularly the dried fruit beetle, *Carpophilus hemipterus* (Linn). For an extensive discussion of fig insects in California, the reader should consult "Fig Insects in California" by Perez Simmons, W. D. Reed and E. A. M'Gregor, *U. S. Dept. Agr. Circ.* 157 (1931).

Fumigation is carried out in tight fumigation chambers. Sulfuring houses, as described under apricots (p. 46) may be used if

the joints are tightly sealed. However, it is considered better to construct a tight chamber for the purpose; these chambers may be either portable or fixed. For a portable chamber, the cubical contents should not exceed 300 cu ft, and should be constructed of plywood in order to minimize weight. Such a chamber is then placed over a stack of trays containing the figs. It is of course, necessary to place the chamber on solid, level ground to prevent leakage between it and the ground. Fixed chambers are usually constructed inside of some other structure in the dry yard because of ease of building. If constructed outside, it is necessary to use material that will withstand the weather. Outside structures must also have a gabled roof and a concrete floor. Permanent chambers usually have a content of about 1000 cu ft, but regardless of whether the chamber is portable or fixed, it is considered desirable to have the cubical contents as some round number. This makes for ease in calculating the amount of fumigant to be used, since most are utilized at the rate of 1 lb per 1000 cu ft of space. It would be a little awkward to calculate the correct amount of fumigant to add to a chamber having a cubical content, say, of 832 cu ft.

It is necessary to vent the chambers rapidly at the end of the fumigation period, and therefore doors are installed at both ends. Some chambers are provided with a venting fan at the end opposite the loading door.

After the chamber has been prepared, it is desirable to test its air-tightness. Mrak and Long[10] describe a simple method which consists of burning sulfur in the chamber. A rag soaked with ammonium hydroxide is then moved along the exterior face of the wall adjacent to all construction joints. If there is a leak, there will be heavy, white fumes of ammonium sulfite.

Fumigants used may be chloropicrin, ethylene oxide and methyl bromide. Since all of these are more or less of a hazard, it is necessary to take proper care in their use and to follow directions of the dealer from whom the material was purchased. Cyanogen should never be used for fumigation because of its extreme toxicity and because of the possibility of toxic residues remaining in the fruit after treatment.

The effectiveness of the fumigant will vary with the temperature

[10] Mrak, E. M., and Long, J. D., "Methods and Equipment for the Sun-Drying of Fruits," *Univ. Calif. Agr. Expt. Sta. Circ.* 350 (1941).

used; low temperatures require longer periods of exposure. Since most fumigants are heavier than air, it is necessary to apply them at the top of the chamber. Mackie and Carter [11] recommend the following dosages of fumigants to be used per 1000 cu ft of space:

chloropicrin, 2 lbs
ethylene oxide plus ethylene dioxide, 9.5 lbs
methyl bromide, 1 lb

The above doses apply regardless of whether the space being fumigated is nearly empty or completely filled with fruit.

The fumigants are supplied in ½- and 1-pound cans or in cylinders, and must be fed into the chambers by various types of applicators which are furnished by the dealer. Cylinders are placed on platform scales so that when the gas is released the cylinder can be weighed and thus the proper dosage assured.

At ordinary temperatures, fumigation is generally for from 15 to 24 hours.

Drying. Figs require but little drying after they have been harvested. The fruit is either placed on trays or loaded into shallow boxes, the latter method being most frequent. Formerly, it was customary to dip the figs in water and then sulfur them before drying, but this practice is now being abandoned. Adriatic figs, however, may still be water-dipped and sulfured (for about 4 hrs) then sun-dried for 2 to 4 days, stacked and further dried. Kadota figs are also sometimes treated in this manner, but neither the Calimyrna nor the Mission varieties are ever sulfured. The exact procedure followed depends upon the past experience of the operator and what he believes will give the best product.

Moisture content of the dried material will average about 24 per cent. When properly dried, the figs are firm and juicy and sirup can no longer be expressed with the fingers.

Sorting. As soon as the figs are dried they are sorted to remove insect-infested, moldy, sour, birdpicked, dirty and smut-damaged fruit. Sorting requires considerable experience and the work is done by individuals familiar with this phase of fig drying. Damaged fruit must not exceed 10 per cent in the sorted material.

[11] Mackie, D. B., and Carter, W. B., "Pest Control in Rural Warehouses and Suggested Improvements," *Calif. Dept. Agr. Bull.* 26 (3), p. 275 (1937).

The sorted fruit is then graded for size, which may be accomplished either by hand or by machines.

Table 11. Grading Sizes for Dried Figs
(*After Mrak and Long*)

Grade	Screen sizes for Black Mission (in)	Calimyrna (in)	White Adriatic (in)
Standard	26/32	30/32	30/32
Choice	30/32	34/32	34/32
Extra choice	34/32	38/32	38/32
Fancy	38/32	44/32	42/32
Extra fancy	over 38/32	over 44/32	over 42/32

Processing. The sorted and graded figs are immersed in boiling water for from 1 to 3 min, the length of time depending upon the condition of the fruit and the most favorable pliability for packing.

The figs may also be processed under pressure in a retort, but this must be done with great care because if processing is too severe the fruit darkens, becomes sticky and may assume a bitter taste.

After processing by either one of the methods described above, the figs are packed into wooden molds of the shape and size of the finished package. Packing in the molds is usually done when the figs are still warm, for they are then more pliable. After cooling, they are wrapped in Cellophane or other suitable transparent wrapping material.

"Sugaring" of dried figs was first recognized by Mrak and his co-workers at the University of California. A white coating consisting of yeast growth and sugar crystals may sometimes form on the surface of unprocessed figs due to incomplete drying or poor ventilation while in storage. In processed figs, the surface coating consists almost entirely of sugar crystals. The presence of this coating may not necessarily decrease the food value of the product.

Dehydration of Figs

The fruit is harvested and prepared as described under sun-drying, and may then be chopped, cut in half, or dried whole. It may be dipped for about ½ min in boiling (1 to 3 per cent) lye and subsequently dipped in fresh, cold water to remove the lye. Generally, a lye treatment is not given, but Kadota figs are sulfured for 2 to 3 hours and then placed in the sun for one day.

Tray loading for drying is at the rate of about 3.0 lbs per sq ft, and during drying the temperature of the product should not exceed

150° F. A temperature of about 140° F should be used for Kadota figs. A humidity of about 5 per cent at the end of the drying period is considered best. Final moisture content of the dried fruit should be from 15 to 20 per cent.

Table 12. Approximate Composition of Dried Figs

Constituent	Partially dried, cooked, unsulfured from Asia Minor[a]	Dried American[b]
Moisture (%)	27.9	24.0
Total Solids (%)	72.1	76.0
Ash (%)	2.2	2.4
Fat (ether extract) (%)	0.4	1.2
Protein (N x 6.25) (%)	3.0	4.0
Reducing sugars (as dextrose) (%)	51.3	55.0
Sucrose (%)	none	
Crude fiber (%)	7.4	5.8
Total carbohydrates (by diff.) (%)	59.1	68.0
Total acid, as malic (%)	—	0.6

[a]Manufacturer's analysis. [b] Chatfield and Adams.

Yield amounts to from 24 to 27 per cent, based on the weight of the fresh fruit as harvested.

Raisin Grapes

Raisin grapes may be either sun-dried or dehydrated, the industry being considered the most important in the dried fruit field. In California, the drying is centered in the San Joaquin Valley, where the season extends from about the 15th of August to the 1st of November.

Varieties. The Muscat, Sultana and Thompson Seedless are used.

Harvesting. About 27 years ago, Bioletti[12] found that the maturity of the grapes used for drying had a most important bearing upon the yield and quality of the product obtained, and that this yield, was of course, reflected in the profits of the venture. As the result of Bioletti's work, Thompson Seedless should not be picked before the Brix of the juice has reached 23°, and in the case of Muscat grapes, the juice should have a Brix of 28°. More recent work in this field has been done by Jacob.[13]

[12] Bioletti, F. T., "Relation of Maturity of Grapes to the Quantity and Quality of the Raisins," *Proc. Intern. Congr. Viticulture,* 1915.

[13] Jacob, H. E., "The Relation of Maturity of the Grapes to the Yield, Composition, and Quality of Raisins." *Hilgardia,* **14,** 321 (1942).

Before harvesting starts, the soil between the rows of vines is smoothed to prepare the ground for the trays upon which the grapes are dried. The trays in the vineyard are tilted to the south (the rows of vines always run east and west) so that they will not be shaded during the morning and afternoon. Having placed the trays in the proper location, the pickers distribute the grapes directly on the trays. Each tray receives about 22 pounds of fruit, or a tray loading at the rate of about 3⅔ lbs per sq ft of drying surface.

Drying. The trays are allowed to remain in their original position until the fruit is partly dried (about 4 days); then they are turned so that the top of the tray becomes the bottom. After about 10 days, the top layer of grapes will be shriveled and they are ready to be turned. This is accomplished by placing an empty tray on top of a full one and turning the full tray on top of the empty one. When the grapes are about two-thirds dry, the trays are collected and stacked. They are allowed to stand in the vineyard for an additional 10 to 14 days for curing.

Sweating. The raisins are considered cured if juice cannot be expressed when the fruit is squeezed between the fingers. They then contain from 15 to 17 per cent moisture. In this condition, they are ready for sweating. First, however, the raisins are passed over a shaker to eliminate sand, insects, and insect eggs.

Sweating is carried out in sweat boxes which are constructed of pine and are usually 38½″×26¾″×7¾″. The boxes must be made strong enough to hold from 135 to 200 pounds of fruit. The ends are therefore made of 1¼″ lumber, the bottom being about ⅞″ thick. The moisture content of the raisins equalizes in the sweat boxes in the same manner as described under apricots (p. 49). The sweating operation requires about 3 weeks.

Soda Dipping of Raisins. From 5 to 15 per cent of Thompson Seedless raisins are soda-dipped before drying. Muscat raisins are never treated in this manner. Some Thompson Seedless are also sulfured after dipping to give "golden bleached raisins."

Soda-dipped raisins are produced in the Sacramento Valley in California where the grapes ripen 2 to 3 weeks earlier than those farther south in the Fresno district. Soda dipping hastens drying, and rapid drying is important in the Valley because the rains start early.

The dipping solution consists of about a 0.6 per cent solution of caustic soda (1 lb of sodium hydroxide to 20 gals water). Some growers prefer sodium carbonate instead of sodium hydroxide. The result obtained by the dipping is called "checking," because numerous tiny cracks are produced in the skin of the grape. The most simple dipping equipment consists of a semicylindrical dump basket with a wire screen bottom hinged to one side of the dipping tank. The dipping tank itself is constructed of black iron and has a capacity of 100 to 200 gals. A large volume of solution is necessary to prevent cooling when the fruit is introduced. Heating of the tank is by means of oil burners, gas, wood or coal. If steam is available, steam coils in the tank are perhaps the best method because of more accurate temperature control. The dump basket is submerged and the fruit introduced. An immersion of about 5 seconds at 200° F is considered sufficient. Prolonged dipping will cause loss of juice. At the end of the immersion period, the basket is raised from the tank by hand and the fruit discharged on a shaker leading to the loading trays.

In large-scale operation, power-driven dipping equipment is used. These may be rotary, consisting of a perforated cylinder mounted horizontally and partly submerged in the dipping bath; or the dipper may consist of a conveyor with baskets which are conveyed through the bath.

Since the degree of checking depends upon the maturity of the fruit, it is impossible to obtain uniform results unless the grapes are uniformly matured. Underripe fruit checks more rapidly than fully ripe.

After dipping, the grapes are rinsed in cold, clean water to remove the lye, and then spread on trays for sun-drying. In about 3 or 4 days they are ready to be turned, and in a week they are in a condition to be stacked. They are then sweated as already described.

Oil-dipped raisins. These are prepared in two ways:

(1) The grapes are dipped cold for from 30 seconds to 3 min in a solution containing 1 lb of sodium hydroxide and 30 lbs of sodium bicarbonate in 100 gals of water, and upon which a film of oil is floating.

The oil used may be raisin seed oil, olive oil or some similar edible oil. This treatment does not check the grapes, but according

to Cruess [14] it apparently removes the wax and bloom. A film of oil is, however, left on the grapes.

(2) The grapes are dipped in a hot solution of the above composition. Drying is carried out as described under soda-dipped raisins. The finished product is darker in color than soda-dipped raisins, and slightly oily.

Sulfur-bleached Raisins. The grapes are dipped in the same manner as soda-dipped raisins, and the washed grapes spread on trays and sulfured (3 to 4 lbs of sulfur per ton of fruit) for 2 to 4 hours. The sulfured fruit is then allowed to stand in the sun for a day. At the end of the first day the trays are turned (*i.e.*, the top becomes the bottom) and at the end of the second or third day, they are stacked. Drying is completed in the stack to avoid undue exposure to the sun, which will cause deterioration. After about 10 days in the stack, the trays are flipped over as described under natural sun-drying. Stack drying requires several weeks, after which the fruit is sweated in the usual manner. If the process has been successful, the raisins will be of a yellowish-white waxy color.

Golden-bleached raisins are prepared in the same manner as sulfur-bleached, with the exception that golden-bleached raisins are dried in tunnel dryers.

Dehydration of Raisin Grapes

Approximately 35 per cent of the raisins prepared are dehydrated. The grapes are treated as described under lye-dipped raisins. Chace *et al.*[15] recommend dipping in a 1 to 3 per cent lye solution for from 5 to 30 seconds. If golden-bleached raisins are to be made, the fruit is also sulfured for about 2 hrs.

Traying. The lye-dipped fruit is spread on the drying trays at the rate of 3 lbs per sq ft.

Drying. At no time during dehydration should the temperature of the product exceed 160° F, and the relative humidity at the end of the drying period should not exceed 5 per cent. Drying requires from 15 to 20 hours.

If the grapes are to be marketed in clusters, they are removed

[14] Cruess, W. V., "Commercial Fruit and Vegetable Products," 2nd Ed., p. 445, McGraw-Hill Book Co. Inc., New York, 1938.

[15] Chace, E. M., Noel, W. A., and Pease, V. A., "Preservation of Fruits and Vegetables by Commercial Dehydration," *U. S. Dept. Agr. Circ.* 619 (1942).

from the dryer when they contain from 15 to 20 per cent moisture. If they are to be stemmed, the moisture is reduced to about 10 per cent. The raisins should be allowed to cool before being stemmed. If the product contains more than 10 per cent moisture, the stems will be too soggy and will clog the stemming machine.

Yield will be from 21 to 27 per cent, based on the weight of the fresh product.

Moisture content of the finished product should be between 15 and 20 per cent.

Handling of Raisins

Stemming. When ready for stemming, the raisins should preferably contain about 10 per cent moisture, and in any case not more than 16 per cent. Stemming is performed by machines. After stemming, the raisins must be "stem-capped," *i.e.*, the small stems adhering to the fruit must be removed. Thompson Seedless and Sultana varieties can be stem-capped without any further drying, but Muscats and Malagas, if they contain more than 12 per cent moisture, must be further dried before they can be successfully stem-capped. Drying is accomplished in some form of tunnel dryer and requires about 5 hours; the initial temperature is 120° F, and the finishing temperature about 180° F.

Seeding. Larger sizes of Muscat raisins are often seeded. Part of the moisture removed for successful stem-capping, as described above, must be replaced, because they cannot be seeded in this dry state. The raisins are treated with water at about 200° F until soft and are then ready for the seeding machine.

Grading. Loose Muscats and Seeded Muscats are graded as follows:

	Screen size, inches
One-Crown	12/32
Two-Crown	17/32
Three-Crown	21/32
Four-Crown	over 21/32

Thompson Seedless are graded as:

	Screen size, inches
Bakers	18/64
Choice	24/64
Fancy	over 24/64

Thompson Seedless grades are classified in accordance with the drying procedure used, *i.e.*, "natural," "sulfur-bleached," "golden-bleached," "soda-dipped."

Muscats, packed in layers, are classified according to the size of the berries. They consist of unbroken bunches of raisins and are carefully handled during drying so that the fruit will not be loosened from the stem. These are called "Vineyard Run," "Three-Crown Layers," "Four-Crown Clusters," and "Six-Crown" or "Imperial Clusters" (the largest raisins).

Fumigation. Since seeded raisins are heated during the process of seeding they do not require fumigation. Seedless raisins, however, must be fumigated according to the technique already described (p. 57).

Table 13 gives the approximate composition of raisins.

Table 13. Approximate Composition of Raisins.*

Constituent	Seeded Muscat	Thompson Seedless
Water (%)	17.3	17.0
Total solids (%)	82.7	83.0
Ash (%)	2.0	1.6
Fat (ether extract) (%)	—	0.2
Reducing sugars (as invert) (%)	70.3	72.7†
Crude fiber (%)	—	0.9
Carbohydrates (by diff.) (%)	76.7	75.9
Total acid (as tartaric) (%)	1.5	1.8

*Manufacturer's analyses. †as dextrose

LOGANBERRIES

Loganberries are dried in the Pacific Northwest to some extent, but production is not great when compared with other dried fruits. Drying is carried out in tunnel or cabinet dryers.

Preparation. The berries may or may not be washed, but if washed, light sprays of water should be used to prevent crushing. Some authorities advocate sulfuring, but this is not necessary.

Traying is at the rate of about 1¼ lbs per sq ft of drying surface.

Drying. Finishing temperatures should not exceed 155° F. Drying requires from 10 to 15 hours.

Moisture content of the finished product should not exceed 10 per cent.

Yield: From 15 to 18 per cent based on the weight of the fresh berries. .

NECTARINES

Nectarines are sun-dried in California in the Sacramento and San Joaquin Valleys. The drying season lasts from about July 15 to August 30.

Varieties. Hardwick, Newboy, Quetta and Stanwich are considered satisfactory for drying.

Preparation and Drying. Freestone nectarines are handled in the same manner as freestone peaches, except that sulfuring and drying times are somewhat less for nectarines. Clingstone nectarines are treated in essentially the same manner as clingstone peaches.

Peaches

Peaches are sun-dried in the San Joaquin and Sacramento Valleys of California, the season lasting from about July 15 to September 15.

Varieties. Clingstone (Midsummer and Phillips) and Freestone (Elberta, Lovell and Muir) are used.

Most of the peaches sun-dried in California are of the Muir variety.

Harvesting. Fruit suitable for drying is firm, not bruised and of uniform color. Careless handling causes bruising and the flesh will then quickly darken. Green, unripe fruit will yield a gray-colored product, poor in flavor and with a woody texture.

Preparation. Freestone peaches are prepared in the same manner as apricots (p. 44). For sun-drying, the freestone variety is preferred because in general it is pulpy, juicy and of good color and flavor. However, in recent years consumer interest in canned freestone peaches has increased, since they have more flavor than canned clingstones. This fact, together with certain quota regulations which cannot be gone into here, has increased the drying of clingstones. This variety is somewhat difficult to pit, and since clingstones contain less sugar than freestones, lower yields are obtained with the former variety.

In preparing for drying, the fruit is thoroughly washed in cold water to remove dirt and part of the skin fuzz. The fruit is then cut around the suture and the pit removed. Cutting and pitting may be done by machine. The fruit may or may not be peeled, but if peeled this is done after pitting, by immersing in a 1½ to 2 per cent sodium hydroxide solution followed by spraying with large volumes of water. Peeled, sun-dried peaches do not yield such an attractive product as peeled, dehydrated peaches.

Pitting and trimming loss will amount to from 15 to 20 per cent.

Sulfuring. Freestone peaches are sulfured for 3 to 5 hours, clingstones for about 6 hours, in the same manner as described for apricots (p. 45).

Drying is carried out as already described for apricots (p. 48). Peaches, however, require a longer drying period than apricots.

Sweating. When the fruit is golden yellow in color, and firm and pliable but not sticky, it is ready to be sweated. This is carried out in sweat boxes as already described (p. 49), or the fruit is piled on a clean, concrete floor.

Grading. Peaches are handled in the same manner as apricots. Table 14 gives the grade sizes as commonly used in California.

Yield: For clingstones will be from 10 to 15 per cent; freestones from 13 to 25 per cent, based on the weight of the fresh fruit.

Table 14. Grading Sizes for Dried Freestone and Clingstone Peaches. (*Mrak and Long*)

Grade	Screen Sizes Clingstones (in)	Lovell (in)	Muir and yellow varieties (in)
Standard	36/32	36/32	36/32
Choice	44/32	46/32	44/32
Extra Choice	48/32	50/32	48/32
Fancy	58/32	58/32	56/32
Extra Fancy	64/32	64/32	64/32
Jumbo	over 64/32	over 64/32	over 64/32

Dehydration of Peaches

Clingstones are generally used if peaches are to be dehydrated, and they are prepared as already described.

Steaming. The halves should be steamed for 5 to 10 min before sulfuring. If not steamed, the trayed fruit should be placed in the sun for a day.

Sulfuring. The halves are sulfured for 15 to 30 min.

Traying. The halves are placed cup side up on trays at the rate of 2.5 lbs per sq ft.

Drying. The temperature should not exceed 155° F and with an initial relative humidity of from 50 to 55 per cent to prevent case hardening. At the end of the drying period, the humidity is reduced to about 25 or 30 per cent. Under these conditions, drying will require from 15 to 24 hours.

Moisture content of the finished product should be from 15 to 20 per cent.

Yield: From 14 to 19 per cent, based on the weight of the fresh unprepared fruit.

Dried peaches will have approximately the following composition (manufacturer's analysis):

Water (%)	24.0
Total solids (%)	76.0
Protein (N x 6.25) (%)	3.0
Fat (ether extract) (%)	0.6
Ash (%)	3.0
Crude fiber (%)	3.5
Total carbohydrates (by diff.) (%)	69.4
Total sugars (%)	51.0
Total acid (as malic) (%)	3.0

Pears

Pears may be either sun-dried or dehydrated, the product obtained by the latter method being superior because of the ability to control drying conditions.

In California, pears are sun-dried in Lake and Mendocino Counties; and in the Napa, Sacramento, Santa Clara and Sonoma Valleys. The drying season extends from about the 15th of July to the 1st of October.

Varieties. The Bartlett is the most common variety, although the Anjou can be used.

Harvesting. Pears for drying are harvested when they are firm for eating but show a blush of yellow through the green color. If picked when in this condition and then allowed to ripen in boxes, a fruit of better texture and flavor is obtained than if allowed to ripen on the tree. Color is not, however, an entirely satisfactory criterion of maturity, and a better method is to subject the fruit to a pressure tester. An instrument for this purpose has been developed by Magness and Taylor and is described in U. S. Department of Agriculture Circular 350 (1925). The tester measures the pressure in pounds required to force a rounded plunger five-sixteenths of an inch in diameter into the fruit to the depth of five-sixteenths of an inch. The peel should be removed from the fruit, and the test made directly on the flesh. Two or three tests should be made on each fruit. Using such an instrument, pears suitable for drying should be harvested when they show a pressure test of about 23 pounds.

The green fruit is allowed to ripen in storage and then sorted out as it ripens. Ripening can be hastened by treating with ethylene, a method discovered by Chace and Sorber.[16] It is not necessary to construct special gassing rooms to accomplish this. The lug boxes of fruit are merely stacked, and a tarpaulin thrown over the stack. Ethylene is then introduced under the tarpaulin, at the rate of one cu ft of gas per thousand cu ft of space. Temperatures should be between 70° and 80° F. By this method, all fruit will ripen uniformly and thus reduce the cost of sorting. The pears will soften in 5 to 6 days, while without ethylene treatment, this requires about 10 days.

Removal of Spray Residue. Bartlett pears are sprayed with lead arsenate and the spray residue must be removed because the fruit is not peeled. Spray residue may be removed as described under apples (p. 39).

Preparation. The fruit is cut in half lengthway, the calyx removed and the stem pulled or cut out. The core is not removed, nor is the fruit peeled. The pears should be cut so that the two halves are equal, or nearly so.

The cut pears are placed on trays with the cut surface up. Before loading the trays on the cars, the fruit is passed beneath sprays of clean water to remove dirt and insects that might be adhering to the material. Water spraying can best be accomplished by passing the trays between a battery of spray nozzles arranged so that the fruit is sprayed from below as well as from above.

Trimming losses will vary from 20 to 25 per cent.

Sulfuring. In Lake and Mendocino Counties, the pears are sulfured from 24 to 72 hours. It is necessary to replenish the sulfur every 8 hours because the sulfur burners will not hold a sufficient quantity to last for the entire sulfuring period. In other pear-drying sections of California, sulfuring is generally less than 24 hours. The riper the fruit, the less sulfuring required.

Drying. In Lake County, the trays of sulfured pears are exposed to the direct rays of the sun for ½ to 2 days, and the trays are tilted toward the south. After about 2 days they are stacked in the shade, usually under open sheds, so that there will be free circulation of fresh air. Separating the trays by blocks of wood

[16] Chace, E. M., and Sorber, Glenn, *The Canner*, p. 14 (Sept. 15, 1928).

enhances drying. It will require from 2 to 4 weeks to complete drying in this manner.

Properly dried pears will be flat and flexible, but not mushy; and they will not be chalky or brown.

Some of the fruit may be overdried, and this is processed as for apricots (p. 49).

Sorting and Grading. The dried fruit is sorted and graded by hand, separating into the various sizes. The largest and best dried pears are termed "Lake County." Tentative sizes for dried or evaporated pears as set forth by the Agricultural Marketing Administration are given in Table 15. The fruit is graded as Grade A (Fancy); Grade B (Choice) and Grade C (Standard).

Table 15. Sizes for Dried or Evaporated Pears
(*Agr. Market. Admin.*)

Size		Width (in)
No. 1.	(Jumbo size)	$1\frac{7}{8}$ or more
No. 2.	(Extra large size)	$1\frac{3}{4}$ to $1\frac{7}{8}$
No. 3.	(Large)	$1\frac{1}{2}$ to $1\frac{3}{4}$
No. 4.	(Medium)	$1\frac{3}{8}$ to $1\frac{1}{2}$
No. 5.	(Small)	$1\frac{1}{8}$ to $1\frac{3}{8}$
No. 6.	(Extra small)	less than $1\frac{1}{8}$

Moisture content of the sun-dried product should be from 10 to 24 per cent.

Yield of sun-dried pears will vary from 14 to 25 per cent, based on the weight of the fresh fruit.

Dehydration of Pears

In the dehydration of pears, the fruit is usually peeled to yield a more attractive product; therefore, it is not necessary to remove spray residue. Peeling is either done by hand or by lye, and the fruit then halved and the core removed as previously described. To prevent darkening, the cut fruit must be kept immersed in water or in a weak (1 to 2 per cent) salt solution.

Trimming and peeling losses will amount to from 20 to 25 per cent.

Steaming. Pears should be steamed for 25 to 30 min before sulfuring. This is necessary in order to get a finished, translucent product. If it is impossible to steam the fruit, it should be trayed and placed in the sun for a day.

Sulfuring. The fruit is sulfured from 15 to 30 min, and at the rate of 5 lbs of sulfur per ton of fruit.

Traying. The cut fruit, core cavity up, is trayed at the rate of 2.5 lbs per sq ft.

Drying. The drying temperature should not exceed 150° F and the relative humidity at the end of the drying period should be from 10 to 20 per cent. Under these conditions, drying time will be from 15 to 24 hours.

Yield: from 12 to 17 per cent, based on the weight of the fresh, unprepared fruit. It will be noticed that this yield is somewhat less than that obtained by sun-drying, but fruit used in the latter process is not peeled.

Moisture content of the finished product should not exceed 10 per cent.

For more detailed information regarding the drying of pears the reader should consult Culpepper and Moon's work: "Drying Kieffer Pears and the Use of the Dried Product," *U. S. Dept. Agr. Circ.* 450 (1937).

Dried pears may have approximately the following composition:

(Modified from Chatfield and Adams).

Water (%)	24.0
Total solids (%)	76.0
Protein (N x 6.25) (%)	2.4
Fat (ether extract) (%)	0.4
Ash (%)	1.7
Crude fiber (%)	6.1
Sugar (%)	36.0
Total acid (as malic) (%)	1.5
Undetermined (%)	27.9

Prunes

Prunes may be either sun-dried or dehydrated. In some instances the initial drying will be by the sun, but weather conditions will force final drying to be carried out in dehydraters. Sun-drying is centered in California in the Napa, Santa Clara, Sonoma, Sacramento and San Joaquin Valleys, where the season lasts from about August 15 to October 1. In Oregon, prunes are always dehydrated.

Varieties. In California, the French (*Petite Prune d' Agen*), Imperial, Sugar and Robe de Sergeant are used. The first-named is the most important, while the last is grown only in limited

quantities. In Oregon, the Italian prune, which is very tart, is used almost exclusively.

Harvesting. In California, the prunes are generally harvested by shaking the trees. Before harvesting takes place, however, the soil in the orchard is rolled so that the fruit will be injured as little as possible when it drops to the ground. In the San Joaquin and Sacramento Valleys, the fruit is harvested by knocking it from the trees. Three harvestings are generally made, the quality of the fruit varying with the harvesting. Fruit obtained from the first harvest is usually inferior to that from the other two and is therefore kept separate. In the interior valleys of California, only two harvestings are made.

Dipping. Prunes should be lye-dipped as soon as possible after harvesting. The machine used for this is the same as that used for dipping raisin grapes (p. 63). The strength of the lye solution and time of dipping depend upon the size and variety of the prune. French prunes are dipped in a solution containing 5 lbs of sodium hydroxide per 100 gals of water, and the dipping solution is maintained at 200° F. The time of dipping is from 5 to 15 seconds. If the skins do not check readily in lye of this strength, it is necessary to use a stronger solution: 10 to 15 lbs of sodium hydroxide per 100 gals of water. Robe de Sergeant requires longer dipping than the French variety. After the lye dip, the fruit is washed by immersion in running water, or by sprays. Imperial variety is dipped in hot water without lye.

If the prunes have been properly dipped, they will show very small cracks over the surface and the skin will not be partly peeled from the fruit. If the peel is loosened, or the prune has burst, it signifies that the lye solution was too weak and immersion too long. If the cracks in the skin are too large and the fruit is partially peeled, the lye solution was too strong.

It is necessary to make a fresh dipping solution every day and its strength must be maintained by proper additions of fresh sodium hydroxide. Accumulation of sugar, dirt and salts from the prunes tends to weaken the solution.

Sizing. Unless the prunes are of fairly uniform size, it is necessary to size them to obtain uniform drying. Sizing is carried out by a "green fruit" sizer and is used in connection with the lye-

dipping machine, the sizer being installed at the discharge end of the dipper.

Drying. The trays used are wooden $3' \times 8'$ standard prune, with either a solid or slatted bottom. These trays are also used for the dehydration of vegetables as described in Chapter 3, but they are not entirely satisfactory for vegetables because of their size and difficulty in handling.

The prunes are loaded on the trays by hand at the rate of 3 to $3\frac{3}{4}$ lbs per sq ft. The loaded trays are spread in the sun in the dry yard until they are about three-quarters dry and then they are stacked. It requires about a week to attain proper condition for stacking, and during this time, the fruit is turned several times to secure even drying. If bad weather sets in before the fruit has been reduced to the proper moisture content, it is necessary to finish drying in a dehydrater. Because the weather is likely to be uncertain during the prune-drying season in California, many producers have abandoned sun-drying and dry their crop in dehydraters.

If sun-drying has been prolonged because of bad weather and it is impossible to finish drying in a dehydrater, the prunes are sulfured for 30 to 40 min to prevent molding and fermentation.

When the fruit has been properly dried, it will contain from 12 to 18 per cent moisture. The flesh is firm and the pit will not slip when the prune is squeezed between the thumb and forefinger.

Sorting. The dried fruit is sorted to remove imperfect pieces. "Chocolates" are prunes that have dried to a chocolate-brown color; "bloaters" and "frogs" are puffy prunes that contain pockets of air usually resulting from fermentation during drying.

Perfect fruit is transferred to lug boxes or burlap bags to be transported to the sweat boxes.

Sweating. This is accomplished either in bins, or by piling the fruit on a clean wooden or concrete floor. If the later technique is used, the fruit is turned over several times during the sweating period. The prunes are generally sweated for about two weeks and by this time the moisture in the fruit should be equalized.

Grading. After sweating, the prunes are placed in clean burlap bags (previously fumigated) and transported to the packing house for grading. Before entering the grader, the fruit is passed over a shaking screen to remove loose dirt and leaves. Actual grading

is based on the number of prunes required per pound, and is accomplished by passing the fruit over screens having holes of different sizes (Table 16).

Table 16. Grading Sizes of Prunes
(*Mrak and Long*)

Number of prunes per pound	Screen size (in)
20—30	over 40/32
30—40	40/32
40—50	38/32
50—60	36/32
60—70	34/32
70—80	32/32
80—90	30/32
90—100	28/32
100—110	26/32
110—120	24/32

Processing. The graded prunes are processed by first washing with rotary spray washers and then draining. The fruit is then dipped in boiling water for from 2 to 4 min, depending upon the size and moisture content of the prunes. Excess water is removed by passing over a shaker.

Yield will vary from 28 to 50 per cent, based on the weight of the freshly harvested fruit.

Dehydration of Prunes

The French and Italian prune are the varieties most commonly used for dehydration. The Imperial may also be utilized. Harvesting is the same as for sun-drying.

Preparation. The Imperial prune is dipped in hot water before drying. The other varieties are lye-dipped as described under sun-drying, and then given a rinse with clean water. It is preferable to "size" the prunes after dipping so that fruits of the same size can be put on the same tray.

Traying is at the rate of 3 lbs per sq ft of drying surface.

Drying. Maximum drying temperature should be 160° F for the Italian prune; the French prune can be dried at 170-175° F. Relative humidity at the start of the drying period should be about 50 to 55 per cent, and at the end about 20 per cent to prevent case hardening. Under these conditions, drying time will be from 20 to 30 hours.

Moisture content of the finished product should not exceed 20 per cent.

Yield is from 33 to 38 per cent, based on the weight of the fresh, unprepared fruit.

Dried prunes will have approximately the following composition (United Prune Growers of California):

Pits (%)	14.9
Moisture (%)	18.4
Total Solids (%)	81.6
Ash (%)	2.2
Protein (N x 6.25) (%)	2.8
Reducing Sugars (as dextrose) (%)	44.3
Dextrose (%)	29.7
Levulose (by diff.) (%)	14.6
Sucrose (%)	2.2
Starch (%)	1.0
Dextrin	negligible
Crude fiber (%)	1.8
Total acid (as citric) (%)	1.2

Dehydration of Other Fruits

Citrus Fruits. At the present time, orange and lemon juices are spray-dried to a limited extent. It is necessary to add a spreader or carrier; otherwise the product will be a gummy mass entirely impractical to handle. The spreader may be whey, skim milk, corn sirup or pectin (100 grade). In the case of corn sirup, a sirup is used which contains about 28 per cent total sugars and 72 per cent dextrins. If the sirup contains less dextrin than this, the sprayed material forms a glassy mass. For every 100 lbs of lemon juice, for instance, about 200 lbs of corn sirup are added. Products of this type contain about 82 per cent corn sirup solids and 18 per cent lemon juice solids. In the case of orange juice, the finished product contains about 75 per cent corn sirup solids and 25 per cent orange juice solids. The product may also be fortified with synthetic vitamin C, citric acid, dextrose and lemon and orange oils. Such a product must then be labeled "Lemon Juice Powder, Synthetic with Vitamin C," to comply with the Federal Food, Drug and Cosmetic Act. If not fortified as above, but merely prepared with corn sirup, a dried orange juice of this type should be labeled "Powdered Orange and Corn Sirup."

If pectin is used as a spreader, it is added at the rate of about 8 per cent, based on the total solids of the juice.

Guavas are not at present dehydrated commercially. The fruit grows quite widely in southern Florida, and is cultivated to a smaller extent in southern California. Guavas are now used chiefly for the preparation of jelly and paste, but because of their high vitamin C content deserve greater attention. Goldberg and Levy [17] found that the fresh fruit contained from 50 to 350 mg of ascorbic acid per 100 g, depending upon the variety and maturity; overripe guavas contained the least. These workers dehydrated the unpeeled fruit by removing the seeds and center pulp, blanching for two minutes and then dehydrating at 130° F. The dehydrated fruit contained from 2000 to 3000 mg of ascorbic acid per 100 g. Recently Mrak [18] has undertaken some researches on the dehydration of six varieties of guavas grown in southern California. He recommends quartering the fruit with stainless steel knives (to prevent discoloration), deseeding, sulfuring for 20 min and then dehydrating at 150° F at a relative humidity of 25 per cent. Preparation losses ran from 21 to 44 per cent, and the drying ratio varied from 5.2 to 6.9 to 1, depending upon the variety. Final moisture content of the dried product varied from 5.9 to 7.4 per cent.

Persimmons are sometimes dehydrated, but it is important to dry only ripe fruit. The fruit is first treated with ethylene in the same manner as described for pears (p. 70) in order to reduce the tannin content. The gassed fruit is then cut in half, spread on trays at the rate of 1.5 lbs per sq ft of drying surface and dried at 150° F. In the initial stages of drying it is preferable to have a relative humidity of from 45 to 50 per cent; this should be reduced to about 10 per cent in the final stages of drying.

Raspberries are washed and then dehydrated at 150° F. If the final moisture content is 10 per cent, the berries reconstitute better than if dried to 5 per cent moisture. The reconstituted product is not entirely satisfactory as a substitute for the fresh or canned commodity. It may be used for preparing jams and preserves. Low-temperature drying (*i.e.*, 70-100° F) yields a better product than that dried at the usual temperatures, but dehydration at such low temperatures is of doubtful economy.

[17] Goldberg, L., and Levy, L., "Vitamin C Content of Fresh, Canned and Dried Guavas," *Nature*, **148**, 286 (1941).

[18] Private communication.

Fruit Bars

These products are of particular interest for use as part of concentrated rations for the army. Such bars generally consist of a mixture of dried raisins, figs, dates, apricots and prunes. To increase the nutritive value, nuts are sometimes added, but fruit bars of this type usually become rancid after comparatively short storage periods. Addition of oat flour tends to retard rancidity.

Table 17. Trimming Losses and Approximate Yields of Some Dried and Dehydrated Fruits

(Data from Mrak and Long, Chace et al., and other sources)

Commodity	Trimming loss (%)	Yield, based on weight of fresh, unprepared fruit (%)	Moisture content of finished product (%)
Apples (rings, slices)	25—35	14—17	not more than 24
Apple, nuggets	25—35	—	not more than 3
Apricots	6—10	15—20	15—25
Bananas	45—60	8—13	3—15
Cherries, unpitted	1—3	24—30	15—20
Cherries, pitted	17—23	18—24	15—20
Cranberries, whole	none	10—14	5—10
Figs	none	24—27	15—24
Loganberries	none	15—18	10
Nectarines	—	12—18	15—20
Peaches, clingstone	10—15	10—15	15—20
Peaches, freestone	13—25	13—25	15—20
Pears, sun-dried	20—25	14—25	10—24
Pears, dehydrated	20—25	12—17	10—15
Prunes	none	28—50	12—20
Raisins, natural	—	16—33	15—20
Raisins, sulfur-bleached	—	20—33	15—20
Raisins, soda-dipped	—	20—33	15—20
Raisins, dehydrated, seeded and stemmed	10—20	21—27	15—20

A satisfactory fruit bar should not become too hard to eat at 0° F, nor too soft and sticky when exposed to temperatures of around 130° F. In accordance with army specifications, the moisture content of fruit bars should be below 20 per cent.*

Cruess and Mogalia [19] have suggested the following formulas for fruit bars:

Fig paste	3 lbs
Finely ground pitted prunes	3 lbs
Finely ground dried apricots	3 lbs
Honey, or heavy invert sirup	1 lb
Fig paste	3 lbs
Finely ground apricots	3 lbs
Muscat seeded raisins	2 lbs

* Army specifications may be obtained from Chicago Quartermaster Depot, 1819 West Pershing Rd., Chicago, Ill.

[19] Cruess, W. V., and Mogalia, J., "Fruit Bar for Army K Ration," *Fruit Prod. J.*, 22, 13 (1942).

Table 18. Approximate Overall Shrinkage Ratio of Certain Dried and Dehydrated Fruits

(*After data from Mrak and Long, with additions*)

Commodity	Approximate Overall Shrinkage Ratio
Apples, rings, slices	6:1 to 7:1
Apricots	4:1 to 7.5:1
Bananas	7:1 to 12.5:1
Cherries, unpitted	3.5:1 to 4.5:1
Cherries, pitted	4.5:1 to 5.5:1
Cranberries, whole	7.2:1 to 10:1
Figs, based on green weight	3:1
Figs, based on harvested weight	1.5:1
Loganberries	5.7:1 to 6.6:1
Nectarines	5.5:1 to 8.5:1
Peaches, clingstone	6.5:1 to 10:1
Peaches, freestone	4:1 to 8:1
Pears, sun-dried	4:1 to 7:1
Pears, dehydrated	5.9:1 to 8.5:1
Prunes	2:1 to 3.5:1
Raisins, natural	
Muscat	3:1 to 5:1
Sultana	4:1 to 6:1
Thompson Seedless	3:1 to 5:1
Raisins, sulfur-bleached	3:1 to 5:1
Raisins, soda-dipped	3:1 to 5:1
Raspberries	5.1:1 to 6.3:1

The ground and thoroughly mixed material is shaped into 2-oz bars approximately $1\frac{1}{8}'' \times 1\frac{1}{8}'' \times 3''$, wrapped in moisture-proof Cellophane and then in heavy Cellophane. The wrapped material must be heated to 140° F to destroy insect life, and then cooled. The pasteurized product is packed in tin containers.

The purpose of the honey or invert sugar in the first formula is to prevent hardening and drying-out in the field.

Table 19. Approximate Pounds Per Cubic Foot of Some Dried Fruits and Weight Per Shipping Ton (40 cu ft)

Commodity	lbs per cu ft	lbs per shipping ton
Apples, rings, slices	55.1	2,204
Apricots	49.2	1,968
Figs	55.1	2,204
Nectarines	49.2	1,968
Peaches	49.2	1,968
Pears	55.1	2,204
Prunes	57.8	2,312
Raisins	42.8	1,712

Suggested Readings

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Chapter 3

Dehydration of Vegetables

Vegetables, with the possible exception of chili peppers, which are dried in large quantities in southern California, cannot be satisfactorily sun-dried. The vegetable dehydration industry has expanded greatly since 1940 and today California produces about 87 per cent of the dehydrated vegetables. Practically the entire output is taken by the armed forces and for Lease-Lend requirements. Sun-drying may be useful in some instances on the farm to preserve food which otherwise would be wasted. For large-scale commercial production, however, vegetables must be dehydrated under controlled conditions of temperature, humidity and air flow.

The dehydration of vegetables is a much more difficult operation than either the sun-drying or dehydration of fruits. There are several factors that must be considered to obtain success, and these will be discussed in some detail. It should also be noted that, although the dehydration of vegetables is a commercial reality, much research remains to be done.

Table 20. Approximate Floor Space Required for Processing and Dehydrating Vegetable

Fresh commodity processed per 24 hours (tons)	Approximate floor space required (sq ft)
5	1500— 4500
10	3000— 8000
20	6000—16000
35	10500—28000
50	15000—45000
70	21000—56000
90	27000—72000

In general, the floor space needed for a plant engaged in the dehydration of vegetables is from 300 to 800 sq ft per ton of fresh vegetables handled per 24 hrs. It is also necessary to have an adequate supply of steam and proper waste disposal facilities (Chapter 6).

Varieties of Vegetables. In the preservation of vegetables by freezing and canning, it has been learned that the selection of the proper varieties is of the utmost importance. The same is true of preservation by dehydration. In general, varieties of vegetables suitable for freezing will be suitable for dehydration.

As yet, not all vegetables have yielded a satisfactory dry product, and it may be that certain vegetables cannot be dehydrated because of their chemical composition or physical structure. As a specific example, asparagus does not yield a satisfactory dehydrated product by any method now used. During dehydration, the stalks collapse and upon rehydration do not regain their original shape. They are tough and unpalatable. This is caused by the histological make-up of the asparagus stalk which does not favor the absorbing of water once the original water has been removed. The tips, however, have a different structure and these can be dehydrated to yield a fairly satisfactory product.

Some varieties of vegetables will acquire a bitter taste when dried, others will lose color and flavor. It is probable that soil and climatic conditions have a bearing upon the quality of the finished product. It is not known, for instance, whether a carrot of the Chantenay variety grown in Florida or Texas will give a dehydrated product of the same quality as a carrot of the same variety grown in California or New York. In warm, moist climates, vegetables are succulent and fast-growing, and may not yield a satisfactory product. This should not be construed as meaning that Florida or Texas vegetables are unsatisfactory for drying. Future research will settle this question.

A mild onion will give an insipid rehydrated product, and it is therefore desirable to use pungent varieties for dehydration. Cabbage of the white varieties quite often yields a dehydrated product having a yellowish-brown color.

Caldwell, Moon and Culpepper[1] have carried out considerable work on comparing the suitability for drying of different varieties of sweet potatoes raised near Washington, D.C.

Maturity of the Vegetable. The stage of maturity of the vegetable to be dried is also an important factor. Dehydration

[1] Caldwell, J. S., Moon, H. H., and Culpepper, C. W., "A Comparative Study of Suitability for Drying Purposes in Forty Varieties of Sweetpotatoes," *U. S. Dept. Agr. Circ.* 499 (1938).

of a young carrot requires a longer period than that of a more mature carrot. On the other hand, a carrot that has remained in the ground until the end of the season, and has become woody, will very probably yield an unsatisfactory dried product. Sweet potatoes that have been stored for several months often give a dehydrated product that is dark, mottled and unattractive in appearance. Stored white potatoes, which have a high sugar content, will yield a dark dehydrated product, especially if dehydrated at temperatures commonly used for freshly dug tubers. Young lima beans are preferable to old beans.

Harvesting. Since it is desired to obtain a dehydrated product of the highest possible vitamin potency, it is important to start with a raw material of high vitamin content. To attain this objective, freshly harvested vegetables must be used. It is now a well-known fact that harvested spinach, if improperly stored, will rapidly lose its vitamin C content. White potatoes, after being dug and then stored, gradually decrease in vitamin C potency.

Table 21. Average Values for Ascorbic Acid (Vitamin C) (expressed as mg/100 g) [Modified data from Fitzgerald and Fellers, *Food Res.*, 3, 109 (1938)]

	Broccoli	Spinach	Peas	Asparagus	Snap beans
As purchased on wholesale market	1.1	0.59	0.22	0.18	0.14
24 hrs later at 70° F.	0.85	0.28	0.21	0.14	0.12
48 hrs later at 70° F.	0.71	0.26	0.20	0.14	0.11

Whenever possible, it is preferable to harvest leafy vegetables in the coolest part of the day. If long-distance trucking is necessary, it is better to have this done during the night when the weather is cooler. Iced lugs would aid in retaining quality of the fresh product. Transportation in refrigerated trucks, although ideal, would be uneconomical.

Methods of Dehydration. Where it is necessary to dry vegetables in the form of slices, dices or strips, tunnel, cabinet or belt dryers, which have already been described in Chapter 1, are used. For the preparation of powdered vegetables for soup mixtures, drum dryers, and sometimes spray dryers, are utilized.

Preparation of Vegetables for Drying. During World War I, many vegetables were dehydrated without any preparation other than washing, and cutting to the desired form. Recent researches have shown quite conclusively that with the exception of onions and garlic, and possibly mushrooms, it is necessary to *blanch*

vegetables before they are dried. Blanching is desirable for the following reasons:

(1) It aids in preserving vitamins during drying.
(2) It makes for better keeping quality of the dried product.
(3) It improves the color of pigmented vegetables.
(4) It aids in more rapid reconstitution of the dried product.
(5) It increases the drying rate.
(6) It expels at least part of the oxygen.
(7) It decreases the bacterial population.

Beckley and Notley,[2] working in England, do not recommend blanching of cabbage, carrots and string beans. They dried their vegetables in a tunnel dryer at 131-158° F. They found that blanching of cabbage, although it gave a product richer in vitamin C, yielded a material that was unpalatable and unattractive after soaking and cooking. Blanched carrots gave a low yield and a product lacking flavor. Sugihara and Cruess[3] also point out that the yield of blanched cabbage, string beans, sauerkraut, carrots and potatoes is less than for the unblanched, but that the reverse is true in the case of spinach, peas, onions and corn.

It is believed, but as yet without adequate scientific evidence, that off-flavors developing in certain dried vegetables are due to enzymes. It is known, however, that blanched dehydrated vegetables will usually keep better than the unblanched. Tests for the destruction of enzymes will be described later (p. 261). Proper destruction of peroxidase is complicated by the fact that this enzyme appears, in some instances, to be regenerated. Just how this comes about and how it can be prevented is as yet unknown.

Washing. Before blanching, it is necessary to wash the product thoroughly to remove dirt. Water for this purpose must be of potable quality. Standard cannery equipment may be used for washing.

Methods of Blanching. There are three methods of blanching: steam at atmospheric pressure, steam under pressure, and hot water. The last method is preferred by the English and Germans, while the first is the one most commonly used in the United

[2] Beckley, V. A., and Notley, V. E., "The Ascorbic Acid Content of Dried Vegetables," *Biochem, J.*, 35, No. 12, 1396 (1941).

[3] Sugihara, J., and Cruess, W. V., "Effect of Blanching on the Dehydration Rates of Vegetables," *Fruit Prod. J.*, 21, 139 (1942).

States. Heating under steam pressure is more properly cooking rather than blanching, and is used in the attempt to be certain of the complete destruction of the enzyme peroxidase.

Water-blanching causes a greater loss in salts and water-soluble vitamins than does steam-blanching. Magoon and Culpepper[4] found losses of water-soluble constituents ranging from 1.5 to 30 per cent. Chace[5] showed serious losses of vitamin C in the water-blanching of certain vegetables (Table 22). Other workers have also found that the longer the blanching period, the greater the destruction of vitamins and loss of minerals (Table 23).

Table 22. Losses in Ascorbic Acid (Vitamin C) Resulting from Steam- and Water-Blanching

(After Chace)

Commodity	Ascorbic Acid mg/100 g (cal. on a moisture-free basis) Raw	Blanched	Loss (%)
Kale, steam-blanched	909	730	19.7
Kale, water-blanched	753	425	43.6
Beets, steam-blanched	52.2	44.5	14.8
Beets, water-blanched	45.4	28.8	36.6
Potatoes, white, steam-blanched	35.5	27.5	22.5
Potatoes, white, water-blanched	34.7	21.7	37.5
Cabbage, steam-blanched	385	331	14.1
Cabbage, water-blanched	398	193	51.5

Table 23. Per cent Retention of Nutrients During Blanching

[*After Adam, Horner and Stanworth, J. Soc. Chem. Ind.*, 61, 96 (1942)]

Vegetable	Minerals			Protein			Vitamin C		
	1 min water-blanch	6 min water-blanch	3 min steam-blanch	1 min water-blanch	6 min water-blanch	3 min steam-blanch	1 min water-blanch	6 min water-blanch	3 min steam-blanch
Brussels sprouts	90	77	83	95	88	89	69	52	89
Carrots, sliced	85	76	90	70	70	74	74	61	78
Carrots, diced	71	67	83	77	79	93	77	54	80
Carrots, whole	94	84	91	90	90	91	84	56	68
Peas, fresh	88	84	95	91	85	96	71	60	84
Potatoes, whole	93	91	90	92	90	90	68	66	61
Stringless beans,									
Whole	91	89	85	100	90	97	93	82	82
Sliced	79	56	80	92	81	87	66	44	64
Swedes, diced	98	83	99	84	76	87	60	43	80

Losses brought about by water-blanching may be reduced by repeated use of the blanching water until the Brix (soluble solids) of the water is about 1.0 or 1.5°. This technique is what the

[4] Magoon, C. A., and Culpepper, C. W., "Scalding of Vegetables for Canning," *U. S. Dept. Agr. Bull.* 1265 (1924).

[5] Chace, E. M., "The Present Status of Food Dehydration in the United States," *Proc. Inst. Food Technologists*, p. 70, (1942).

English call "serial scalding." In the case of some vegetables, water-blanching gives a better-appearing dried product. The addition of salt to the blanching water intensifies the green color of Savoy cabbage.

If blanching is by steam at atmospheric pressures, this is best accomplished in a continuous blancher where the material is loaded upon a mesh belt which slowly travels through a tunnel having steam jets above and below the belt. There should be an adequate flow of steam so that the material attains a temperature of at least 190° F within one minute. Blanching time is not measured until the product has reached 190° F. It is necessary to avoid overloading the belt, so that every piece of material will come in contact with the steam. Loadings of the blanching belt should not greatly exceed the square foot loadings of drying trays. If a mesh belt is not used, and it is impossible to have steam jets below the belt, loadings should be lighter.

Steam blanchers should not have a stack in the middle. A small vent is provided to exhaust air when the blancher is first started. Each end of the blancher should have a canvas curtain to retain the bulk of the steam within the equipment and yet allow the air to flow out along with excess steam. In some blanchers, water sprays are installed outside of the entrance end, and they may also be provided outside of the exit. Cooling the blanched vegetables with sprays of water is a common practice in Germany.

The quantity of steam necessary for blanching will vary, depending upon steam losses from the blancher, but will generally range from 1 to 3 bhp per ton of unprepared vegetables handled per 24 hrs.

Steam blanching may also be carried out in blanching cabinets. Here the trays of vegetables are placed on angle-iron runways and subjected to steam; or the whole truck-load of trays may be pushed into the blanching cabinet. It is extremely difficult to obtain uniform blanching with this type of equipment and quite often the material in the center of the trays is underblanched. It also requires a longer period for the material to come to the desired temperature than in the case of a belt blancher.

In blanching under pressure, the vegetable is placed in baskets in a pressure cooker and heated to about 240° F. There is some

question as to the effect of this treatment upon the quality of the product.

In hot-water blanching, the material may be placed in baskets and then conveyed through a tank of hot (not less than 190° F) water, or the product may be conveyed on a belt through the tank. In this case it is necessary to have a second belt to hold the vegetables submerged on the first. In hot-water blanching, it is desirable to use a soft water. Hard water may cause a toughening of the product.

The time (or amount) of blanching is important: under-blanching will not give the results desired, and over-blanching renders the material mushy or flabby and thus makes drying more difficult.

Drying. The tunnel, belt and cabinet type dryers are most commonly used for the dehydration of vegetables when it is desired to retain the original shape of the pieces. These dryers have already been described in Chapter 1 and no further discussion will be attempted. Drying temperatures used for the different vegetables will be indicated under each commodity. In considering these temperatures, the reader should bear in mind that they are only approximate and the quality of the dried product made at any given temperature will vary in accordance with the chemical composition of the fresh vegetable, climatic conditions, soil characteristics, irrigation and fertilizer practices under which it was grown.

Table 24. Approximate Average Drying Time of Some Vegetables Dehydrated in a Counter-Current Tunnel Dryer (air velocity, approx. 500 linear ft per min)

Commodity	Max. dry-bulb temp* (°F)	Form of piece being dried	Approx. average time of drying (hrs)	Final Moisture Content (%)
Beans, lima (shelled)	150°	whole bean	8.0	5
Beans, snap	150°	$\frac{3}{4}$" cut	7.5	5
Beets	165°	$\frac{1}{4}$" strips	7.5	5
Cabbage	145°	$\frac{1}{4}$" shreds	6.0	4
Carrots	165°	slices	8.0	5
Celery	150°	cut stalks	7.5	5
Corn	165°	kernels	6.5	5
Onions	135°	slices	7.5	4
Peas (shelled)	150°	whole	7.5	5
Potatoes, white	150°	$\frac{3}{16}$" strips	6.0	6
Potatoes, sweet	165°	slices	10.5	7
Pumpkin	160°	slices	10.6	6
Rutabagas	160°	slices	9.5	5
Spinach	180°	trimmed leaf	6.0	4

*At dry (unloading) end of tunnel

Case-Hardening. This phenomenon is brought about when surface evaporation from the tissues exceeds the rate of moisture diffusion from the interior to the surface. The surface of the product then sears over, forming a tough skin, and drying is retarded. In general, case-hardening is not an especially serious factor in the dehydration of vegetables with the possible exception of potatoes and peas, but is of considerable importance in drying fruits. It is retarded by increasing the relative humidity of the air, particularly during the initial drying period, but of course this also prolongs drying.

Moisture Content of Dehydrated Vegetables. Vegetables must be dried to a lower moisture content than most fruits because in the latter products the high percentage of sugar and fruit acids aid in keeping the product. Gore and Mangels[6] found that the

Table 25. Effect of Moisture Upon Palatability of Blanched Dried Vegetables Stored in Air at 90° F.
(*After Chace*[5])

Vegetable	Storage time (wks)	Moisture (%)	Palatability* rating
Carrots	0	7.2	2.0
	16	7.2	3.0
Carrots	0	9.8	2.0
	16	9.8	3.8
Carrots	0	13.5	2.0
	16	13.5	4.0
Cabbage	0	3.6	2.6
	16	3.6	3.1
Cabbage	0	8.2	2.6
	16	8.2	4.0
Cabbage	0	10.2	2.6
	8	10.2	4.1

*1 Excellent
2 Good
3 Fair
4 Without odor or flavor but with no distasteful quality
5 Distasteful or disagreeable odor or flavor

following vegetables, when dried without blanching, retained their quality (in respect to color and flavor) if they did not contain more than the following designated moisture content:

carrots,	not	more	than	7.39%
turnips,	"	"	"	5.00
onions,	"	"	"	6.64
spinach,	"	"	"	5.38
cabbage,	"	"	"	3.34

[6] Gore, H. C., and Mangels, C. E., "The Relation of Moisture Content to the Deterioration of Raw-dried Vegetables," *Ind. Eng. Chem.*, 13, 523 (1921).

Researches since those of the above workers have shown that in the case of some dried vegetables these moisture contents are too high. Table 25 shows the effect of moisture on the deterioration of blanched, dried vegetables after storage at about 90° F. It will be noticed that a rating of "1" is considered as "excellent." It is very doubtful that any product, even the fresh commodity, would ever receive this rating.

Shrinkage Ratio of Vegetables on Drying. In Table 26 is given the approximate overall shrinkage ratio of some vegetables commonly dehydrated. This ratio will vary widely with the variety, growing conditions, time of harvest, grade of raw material and loss

Table 26. Approximate Overall Shrinkage Ratio of Some Vegetables
(*Dehydration Committee, Bureau Agr. Chem. & Eng., with additional data*)

Commodity	Approx. overall shrinkage ratio
Beans, snap	10 to 1
Beans, Lima (unshelled)	9 to 1
Beets	13 to 1
Cabbage	19 to 1
Carrots	10 to 1
Celery	20 to 1
Corn	10 to 1
Onions	14 to 1
Peas (unshelled)	9 to 1
Potatoes, white	7 to 1
Potatoes, sweet	4½ to 1
Pumpkins	15 to 1
Rutabagas	10 to 1
Spinach	18 to 1
Tomatoes	21 to 1

in preparation. Each dehydrator should watch his own shrinkage ratio as a basis of plant operation. In this connection, the dehydration engineer does not express moisture of the material as per cent, but rather on a "dry basis", *i. e.,* as the ratio of water content to dry matter. The weight of dry matter going into a dehydrater will be the same as that taken out. The amount of water changes, but the dry matter does not. Shrinkage may be calculated from the formula:

$$\frac{T_o+1}{T_f+1}$$

where T_o = lbs of water per lb bone-dry material in the fresh product, and T_f = lbs of water per lb bone-dry material in the dried product.

As an example, Irish potatoes, prepared and ready for the

dryer, have about 78 per cent moisture; when properly dried they have 6 per cent moisture. Then

$$\frac{\frac{78}{22}+1}{\frac{7}{94}+1}=\frac{3.5+1}{0.07+1}, \text{ and will give } \frac{4.5}{1.07}$$

or a shrinkage of 4.2 to 1. It should be noted that this shrinkage is of the prepared material going into the dryer, and does not include loss in preparation.

Directions for Dehydrating Various Vegetables

The preparation and dehydration of different vegetables may vary considerably in details and therefore the directions for each are presented in the following pages.

Asparagus

Asparagus is not at present being dehydrated commercially, and indications are that it will not yield a satisfactory product by any method now known to be used, especially if the entire stalk is utilized. The tips yield a fairly satisfactory product, but if dried at too high a temperature they have a malty flavor.

If the tips are to be dehydrated, they are washed and then steam-blanched for 4 or 5 minutes. Traying is at the rate of about 1.5 lbs per sq ft. During dehydration, temperature of the product should not exceed 140° F and preferably 135° F. Final moisture content should not exceed 5 per cent.

Beans, Baked

Esselen and Davis[7a] describe the following method as being satisfactory for dehydrating baked beans:

Varieties. California pea, kidney and yellow-eyed beans may be used. The baked, dehydrated product from kidney beans requires a longer period of reconstitution than the other two varieties. The beans may split open during dehydration, but kidney and pea beans show this tendency to a less degree than yellow-eyed. Esselen and Davis consider pea beans as the most satisfactory type to use.

[7a] Esselen, W. B., and Davis, S. G., "Dehydrated Baked Beans," *Canner*, 95, No. 20, p. 18 (1942).

Baking. The dry beans are allowed to soak for 12 to 16 hours and then rinsed with clean water. The cleaned beans are blanched for three minutes in boiling water and then filled into two-quart bean pots. To each pot is added ½ lb of salt pork and brine containing flavoring ingredients.* Each pot should have sufficient water to cover the beans. The material is slowly baked for 5 to 6 hours at 350° F. Water should be added during the baking period to keep the beans covered, but at the completion of baking only a small amount of liquid should remain in the pots.

Traying. The baked product is allowed to cool for 30 min and then loaded on the trays at the rate of 1¼ lbs per sq ft of drying surface. The salt pork must be discarded before traying the beans. To prevent leakage of the liquid from the beans, the tray bottoms should be covered with clean waxed paper or a water-proof paper. Enameled trays are preferable, if they can be obtained.

Drying. Dehydration is carried out at 140° F and drying generally requires from 8 to 10 hours.

Moisture content of the finished product should be from 3 to 4 per cent.

BEANS, GREEN

Green beans are prepared as in regular cannery practice. It is desirable to use stringless beans which require less labor in trimming. As the beans become older they develop strings.

Varieties. Tendergreen, or Asgrow stringless green pod, Burpee Stringless green pod, Giant stringless, Full Measure, U. S. No. 5 Refugee, Idaho Refugee, Blue Lake, Kentucky Wonder.

Preparation. The vegetable is first sorted to remove spotted, sunburned or flat beans, and then snipped, washed and either sliced lengthways or across by machines. If the pods contain strings, these must be removed before slicing.

Trimming loss will amount to from 8 to 13 per cent.

Blanching. Nichols *et al.*[7] recommend a steam blanch of 15 to 20 min. Other authorities advocate blanchings of from 5 to 10 min. A 15-min steam blanch is probably best, and the product

* Each pot contains 2 teaspoons of salt, 1 teaspoon of ground mustard, 4 tablespoons dark molasses, 2 tablespoons vinegar, 1 qt warm water.

[7] Nichols, P. F., Powers, C. R., Gross, C. R., and Noel, W. A., "Commercial Dehydration of Fruits and Vegetables," *U. S. Dept. Agr. Bull.* 1335 (1925).

should be cooled with sprays of water immediately after blanching.

Traying is at the rate of ¾ to 1.0 lb per sq ft of drying area.

Drying. At no time should the temperature of the product exceed 165° F.

Yield will vary from 8 to 12 per cent, based on the weight of the fresh, unprepared product.

Moisture content of the dried product should not exceed 5 per cent.

Improperly dried beans will have a leathery or pock-marked appearance, will be tough and possess but little flavor.

Beans, Lima

Dehydrated lima beans are better than ordinary dried beans of commerce that have been ripened on the vine.

Varieties. Young, tender beans should be used, the Ford Hook yielding a very satisfactory product.

Preparation. The harvested beans are shelled from the vine with a modified pea-vining machine used in canning. The shelled beans are then sorted to remove over-mature beans, which are dried separately. Sorting is accomplished by means of floating the beans in a salt solution of definite concentration, in which young beans float and over-mature beans sink. The exact concentration of the salt solution must be determined by the dehydrator to meet his particular needs in dealing with the beans he has on hand. Machines for separating beans in this manner are sold by cannery equipment manufacturers.

Preparation loss will amount to from 40 to 45 per cent.

Blanching. The beans are blanched in flowing steam for about 5 min.

Traying is at the rate of 1 to 1¼ lbs per sq ft of drying area.

Drying. At no time should the temperature of the product exceed 150° F.

Moisture content of the dried product should not be more than 5 per cent.

Yield will amount to from 8 to 14 per cent, based on the weight of the fresh product.

The dehydrated product may be mixed with dehydrated corn to prepare succotash.

Beets

Beets are prepared in the form of slices, cubes and strips. If properly handled, they yield a very satisfactory dried product.

Varieties used are Detroit Dark Red, Morse Detroit and Ohio Canner, the first-named being considered the best.

Preparation. The vegetable should be washed to remove dirt and then cooked whole for 30 to 40 min in flowing steam. In this case a continuous blancher cannot be used and a retort is the most satisfactory equipment. The time can be materially decreased by cooking under about 10 lbs steam pressure. The beets should be thoroughly cooked and then peeled either by an abrasive peeler or by hand. Hand-peeling is more satisfactory because there is less waste and bleeding. The vegetable may also be peeled in a flame peeler (p. 109), but in this case peeling is accomplished prior to cooking.

The peeled vegetable should be trimmed to remove roots and damaged parts. This operation should be done after cooking; if not, there is loss by bleeding and the trimmed beet will have a lighter color after drying than the untrimmed parts.

The cooked and trimmed beets are then cut into slices (from 3/16″ to 4/16″ in thickness); cubes (from 3/16″ to 6/16″ on a side); strips of not less than 3/4″ in length, and in cross-section not less than 3/16″ nor more than 6/16″.

Peeling and trimming loss, when an abrasive peeler is used, will amount to about 25 per cent. In hand peeling, the procedure followed in the canning of beets, loss is considerably less, and if cheap labor is available, it is the preferred method.

Traying is at the rate of about 1¼ lbs per sq ft of drying area.

Drying Temperature. At no time should the temperature of the product exceed 165° F.

Moisture content of the finished product should not exceed 5 per cent.

Yield will average about 7 per cent, based on the weight of the fresh, unprepared beets.

Broccoli

This is not at present being dried commercially. Mrak and Cruess[8] recommend washing the trimmed stalks and blanching in

[8] Mrak, E. M., and Cruess, W. V., "The Dehydration of Vegetables," Special Subsistence Bull., Quartermaster Corps, U. S. Army, 1941.

steam for 10 to 12 min. The blanched material is spread on trays "one layer deep." This would probably correspond to a tray loading of ¾ to 1.0 lb per sq ft of drying area.

Drying is carried out in such a manner that the temperature of the product at no time exceeds 160° F. Mrak and Cruess recommend a finishing temperature of 150° F. The moisture content of the dried product should not exceed 5 per cent, and should preferably be 3 per cent.

Yield will amount to from 8 to 12 per cent, based on the weight of the fresh, unprepared product.

Brussels Sprouts

At present, these are not being dried commercially, but during the last war there was considerable production. The vegetable is prepared by washing and cutting the sprouts from the stalk. The sprouts may be dried whole or cut in half.

Blanching is in flowing steam for about 5 min. The blanched vegetable is trayed at the rate of 1 to 1¼ lbs per sq ft of drying area, and dried so that at no time will the temperature of the product exceed 160° F.

Moisture content of the dried product should preferably be not more than 3 per cent.

Cabbage

This vegetable is generally dehydrated in the form of shreds made by cutting the cored heads in a kraut cutter so that the strips are about ¼″ wide.

Varieties. Green varieties are preferred (such as Savoy); white varieties such as Copenhagen are deemed satisfactory but must be handled with greater care than Savoy. Red varieties are used only to a limited extent. Kraut cabbage is extremely difficult to handle because it generally gives a brown dried product. Some authorities claim that it is impossible to dry kraut cabbage; others state that it can be done if proper precautions are taken to see that the product is not overblanched and that drying temperatures are kept below 150° F.

Preparation. The outer leaves that are wilted, or injured by insects, should be removed. Most trimmers have the tendency to remove excessive amounts of the outer leaves; this not only

increases the trimming loss, but also reduces the vitamin C content, because the outer leaves contain more of this vitamin than the inner.

After trimming, the head is cored by machine. Some cabbages, especially those grown in the Imperial Valley of California, are difficult to core because the core does not run straight through the center of the head.

Courtesy U. S. Dept. of Agriculture. (Photograph by Lee)

FIG. 16. Cabbages to be dehydrated are first cored.

The cored cabbage is then put through a kraut cutter so adjusted that strips about ¼ in wide are obtained. Finer shredding causes the material to collapse during blanching and it will stick to the drying trays, thus increasing the drying time.

Cut cabbage may rapidly lose its vitamin C content, but the extent of this loss depends upon the method of cutting. Pyke[9] showed that grating of cabbage resulted in a loss of 34 per cent of its vitamin C content in 5 min. Shredding caused a loss of 10 per cent,

[9] Pyke, M., *Nature*, **149**, 490 (1942).

but it is doubtful whether this loss could be considered of practical significance. When Pyke shredded cabbage with a sharp knife, no loss of vitamin C resulted. Lampitt, Baker and Parkinson [10] confirmed Pyke's results and showed that there was a correlation between mechanical breakage of the cells and loss of vitamin C.

In view of the above results, it is important to see that the knives of the cutter are sharp and to blanch cabbage as soon as possible after shredding. It is not advisable to hold the cut material for more than one hour before blanching. Even this should not be done unless the cut vegetable is held under a 1 per cent salt solution.

Courtesy U. S. Dept. of Agriculture (Photograph by Lee)

FIG. 17. Inspection of cabbage after dehydration.

Blanching. This is best accomplished in flowing steam for 1½ min at 190° F. The time will vary according to the type of cabbage being handled. Savoy or other green varieties will stand more blanching without injury than white varieties such as Copenhagen. In blanching white varieties, the material should be rapidly cooled with sprays of water immediately after blanching. This can be accomplished by installing spray jets at the exit end of the blancher.

[10] Lampitt, L. H., Baker, L. C., and Parkinson, T. L., *ibid.*, 149, 697, (1942).

Blanching at 190° F in a 1 per cent salt solution will yield a better-colored product than that obtained by steam blanching. If such a procedure is selected, the halved or quartered head is blanched, because salt-water blanching of shreds causes too great a loss of vitamin C. The blanched halved or quartered heads are then cut in a kraut cutter. The objection to this method is the extra operation of halving or quartering the heads, which must be done by hand.

The British prefer to treat the shredded cabbage with a solution of sodium sulfite instead of blanching. This causes a greater retention of vitamin C during drying and subsequent storage, but the use of sulfur dioxide in foods is frowned upon by most American food authorities.

Traying. The blanched material is spread on the drying trays at the rate of about ¾ lb per sq ft of drying area. It is preferable to allow the blanched material to fall directly upon the drying trays from the blancher, because handling the blanched cabbage tends to make it mushy and to increase the drying time.

Drying Temperature. At no time should green varieties (such as Savoy) attain a temperature higher than 150° F, and non-green varieties should not exceed 145° F.

Moisture content of the finished product should not exceed 4 per cent.

Yield will vary from 4 to 10 per cent, based on the weight of the fresh, unprepared material.

Carrots

These are dried in the form of slices, cubes and strips.

Varieties used are Red Core Chantenay, Imperator, Nantes Early, Scarlet Horn, Long Orange and Morse Bunching. These should be well-colored and orange-red throughout and should not be woody. Although old carrots * contain more carotene than young ones, the former do not yield a satisfactory dried product. Some dehydrators use carrots that have remained in the ground all season and claim that a satisfactory dried product can be obtained from such material, but this is open to question. However, very

* By "old carrots" is meant the vegetable that has been allowed to remain in the ground past the optimum eating stage. It does not mean carrots that have been pulled at the proper maturity and then placed in cool storage.

Courtesy U. S. Dept. Agriculture. (Photograph by Knell)

FIG. 18. Pulling and packing carrots on a New York State farm for delivery to a nearby dehydration plant. The dehydration process cannot improve the quality of a raw product. Hence dehydration plants, putting up food for our armed forces and for shipment to our allies, accept only fully ripe vegetables in prime condition.

young carrots should not be used because they contain less carotene than older ones (Table 27).

Table 27. Effect of Stage of Maturity of Carrots on Carotene Content.†
(Dehydration Committee, Bureau Agr. Chem. & Eng.)

Date of Sampling	Carotene (mg/100 g fresh wt)
January 26, 1942	8.75
February 12, 1942	7.33
February 26, 1942	9.04
March 9, 1942	12.60
March 21, 1942	12.00
April 6, 1942	12.70
May 19, 1942	17.60
July 2, 1942	13.80 (sample was moldy)

†From the Imperial Valley, California.

Carotene content of the different varieties may vary somewhat, especially as they mature (Table 28).

Preparation. The vegetable should be thoroughly washed and then peeled by any suitable means. There are three methods of peeling: by abrasive, flame, and lye.

If an abrasive peeler is used, the carrots must first be sized in groups of 3 or 4 different diameters and each group peeled separately in order to avoid excessive peeling losses. The vegetable should not be peeled too deeply because the carotene is largely in the outer part of the root. Peeling and trimming losses will amount to from 20 to 30 per cent.

In flame-peeling, the outer part of the root is burned off either by direct contact with a flame, or by radiant heat. Flame-peeling is described in more detail under the preparation of potatoes (p. 109). After flame peeling, the root is thoroughly brushed and washed to remove the charred material. Peeling and trimming losses in flame-peeling will amount to about 5 per cent.

Lye-peeling is accomplished by immersing the carrots in a boiling 4 per cent solution of sodium hydroxide followed by thorough washing in water to remove the excess lye. The lye solution will become weak from dilution and dissolving of material from the carrots and it is necesary to check the strength of the bath by frequent titrations. Peeling and trimming losses are about the same as those for flame-peeling.

Table 28. Carotene Content of Different Varieties of Carrots*
(*Modified from Hanna, Univ. Calif.*)

Variety	Carotene Content (mg/ [slant[100 g, dry wt) July 1, 1942	Aug. 1, 1942	Sept. 1, 1942
Imperator	44	79	80
Danvers Half Long	56	72	74
Chantenay	87	—	96
Morse Bunching	56	62	80

*Grown at Davis, Calif. Planted March 12, 1942.

Some carrots show a green core starting at the crown. This is caused by the crown being exposed to sun because of improper banking. During trimming, this green core should be completely removed, and since the green coloration may extend a considerable distance from the crown, trimming losses will be great. There have been suggestions that this green portion may have toxic properties, but there is no evidence to substantiate this.

The peeled and trimmed root is cut into slices from 3/16″ to

4/16″ thick; or into cubes from 3/16″ to 6/16″ on a side; or in strips not less than 3/4″ in length, and in cross-section not less than 3/16″ nor more than 6/16″.

Blanching. After cutting to the desired shape, the carrots should be immediately blanched; it is not advisable to allow the cut material to stand for more than 30 min before blanching. Blanching should be in flowing steam at 190° F for about 4 min, or until peroxidase has been destroyed (p. 263). Improperly blanched carrots

Courtesy U. S. Dept. of Agriculture. (Photograph by Knell)

FIG. 19. With special spreaders, the operators spread blanched, diced carrots, in even, thin layers on drying trays.

will bleach after being dried and there will be a rapid loss of carotene. Some dehydrators prefer to blanch under pressure in retorts at 240° F for about 10 min. Such treatment is in reality cooking, and is more expensive than ordinary steam-blanching both from the standpoint of additional labor required and from additional steam consumption.

The British prefer water-blanching of carrots, followed by spraying with a weak (2 or 3 per cent) salt solution.

Traying is at the rate of 1¼ lbs per sq ft of drying area.

Drying Temperatures. At no time should the temperature of the product exceed 165° F.

Courtesy U. S. Dept. of Agriculture. (Photograph by Lee)

FIG. 20. The dehydrated vegetable runs off from the tray on which it was dried into a hopper that leads to a temporary container below.

Moisture content of the dried product should not exceed 5 per cent. Some dehydrators claim that the moisture should not be over 1 per cent, or even less. However, it is not at present economically possible to attain these low moistures in either tunnel or cabinet dryers. Vacuum dehydration is therefore necessary for them, and whether the consequent increase in cost justifies the advantages of extremely low moisture content must be shown by future research.

Yield will vary according to the maturity and variety of carrot (Table 29).

Table 29. Drying Ratio of Carrots*
(*Modified from Hanna, Univ. Calif.*)

Variety	Overall Shrinkage ratio.		
Time Since Planting (days)	110	141	172
Danvers Half Long	8.3	8.7	8.4
Imperator	8.3	7.8	7.2
Morse Bunching	7.8	7.7	6.8
Red Cored Chantenay	10.3	9.8	7.5

*Grown at Davis, Calif.

Cauliflower

The dehydration of this vegetable has been merely experimental and is handled in essentially the same manner as Brussels sprouts.

Celery

Celery is not dried extensively and is mainly utilized in soup mixtures. It is also ground to a powder after drying for use as a seasoning. Celery is an expensive crop to grow, and the dried product must, therefore, command a higher price than most other dehydrated products.

For drying, crisp stalks are preferred, and these are broken from the bunch or head. The stalks are separated and given an acid dip, if spray residue is present (p. 39), and then washed to remove the acid.

If leaves are to be dried, the brown and yellow leaves are removed, acid-dipped in the same manner as the stalks, and then washed.

Celery for soup mixtures is usually prepared by finely shredding the stalks and leaves. It is preferable to dry the leaves and stalks separately because the former dehydrates more rapidly. Stalks are cut in $\frac{1}{2}$ to $\frac{3}{4}''$ lengths and blanched in flowing steam for about 1 or 2 min. If the product is to be used for powdered celery the material is not blanched, because blanching causes some loss in flavor.

Trimming and preparation losses amount to from 18 to 23 per cent.

Traying is at the rate of 1 to 1$\frac{1}{4}$ lbs per sq ft for cut stalks and about 1 lb per sq ft for shredded stalks and leaves.

Drying. The temperature of the product should at no time exceed 150° F.

Moisture content of the dried product should not exceed 4 per cent.

Yield will vary from 4 to 8 per cent, based on the weight of the fresh material.

Corn

This product is dried as whole kernels and should not be confused with ordinary dried corn.

Varieties. Any of the sweet varieties are suitable, and Country Gentleman and Golden Bantam will yield good dried products. Although there are no published experimental data, types of similar horticultural quality such as Golden Cross Bantam may be suitable for dehydration.

Preparation. The corn should be harvested when young and tender and full of "milk." The husk is removed by a husker, as in regular canning practice, and the husked ears trimmed to remove any worm damage. The silk does not have to be separated at this stage because it can be more easily removed from the dried product by a fanning mill.

Trimming and preparation losses will amount to from 60 to 65 per cent.

Blanching. The husked ears are blanched in flowing steam for about 15 min, or until the "milk is set." Young corn will require longer blanching than old. When the milk has been properly set no liquid will exude when the kernels are cut with a knife. It is also important that peroxidase be inactivated (p. 263).

After blanching has been completed, the kernels are cut from the cob by machine.

Tray loadings are at the rate of about ¾ to 1 lb per sq ft of drying area.

Drying Temperatures. At no time should the temperature of the product exceed 165° F. However, at the beginning of the drying period, when the product is still moist, a dry-bulb temperature of 170° F can be used.

The dried product is fanned to remove silk and pieces of cob.

Moisture content of the dried product should not exceed 4 per cent.

Yield. From 8 to 12 per cent, based on the weight of the fresh material.

Garlic

This is prepared in powdered form and is one of the dehydrated products that survived the last war. The "buttons" are separated and the outer paper-like skin removed. This is generally accomplished by hand, although some authorities recommend peeling in an abrasive machine. The peeled material is then sliced.

Blanching. It is not necessary to blanch garlic.

Traying is at the rate of 1 to 1¼ lbs per sq ft of drying area.

Drying. At no time should the temperature of the product exceed 140° F. Because drying temperatures are so low, the material is generally taken from the dryer before the final desired moisture content is attained, and drying finished in a bin. Final drying can be accomplished in the dryer, but this reduces the drying capacity.

Moisture content of the finished product should not exceed 4 per cent.

The finished product is ground in a hammer mill and then sifted to give a smooth powder.

Greens

Under this classification is grouped spinach, kale, chard, beet, mustard and turnip greens. The material is preferably dried whole after trimming and the leaves should not be cut into strips. If the different greens are sold as mixtures, they should be properly labelled in accordance with the Federal Food, Drug and Cosmetic Act.

Varieties. According to our present knowledge, varieties generally used as fresh vegetables are satisfactory for dehydration. It is not probable, however, that New Zealand type of spinach could be economically dried because of the large stems common to this variety; the stems would have to be removed and the yield of dried product would be extremely low.

Preparation. Greens must be quickly handled because they rapidly lose their vitamin C content. By merely standing overnight in the plant at ordinary temperatures they may lose 50 per cent of their vitamin C (Table 21, p. 83).

Upon receipt at the plant, the material should first be thoroughly washed with sprays of clean water to remove part of the sand and dirt. The vegetable is then sorted and trimmed to remove roots,

stems and damaged and discolored leaves. Great care should be exercised not to bruise the leaves because bruising accelerates the loss of vitamin C. The more stems removed, the lower the yield of finished product, but the stem content of the dried product should not exceed 10 per cent. The stems contain considerably less vitamin C than the leaves, and require longer drying time.

After trimming, the material should be thoroughly washed in clean, cold water. Proper washing is difficult and there is a tendency in some instances to be careless. A common plant process to judge the thoroughness of the washing is to chew a raw leaf and if it does not have a gritty feel between the teeth, washing may be considered complete.

Trimming loss will vary with the green: spinach, 45 to 65 per cent; kale, 55 to 60 per cent; mustard greens, 30 to 40 per cent; chard, 45 to 55 per cent.

Blanching is carried out in flowing steam and the time will vary with the green. Thus, spinach is blanched for about 2 min; chard, 3 to 4 min; mustard greens, 2 min; kale, 2 min. In general, blanching is continued until the midribs are translucent. Over-blanching should be avoided because this will render the material soggy, cause it to stick to the trays and prolong drying time. Undue handling of the blanched product should be avoided because of danger of matting.

Traying is at the rate of ¾ to 1 lb per sq ft of drying area.

Drying Temperature. At no time should the temperature of the product exceed 180° F.

Moisture content of the dried material should not exceed 4 per cent.

Yield will vary with the green: spinach, 5.5 to 6 per cent; kale, 3 to 5 per cent; mustard greens, 8 to 9 per cent; chard, 4 to 5 per cent; all based on the weight of the fresh material.

Onions

These are prepared in the form of slices (sometimes called chips) and as a powder. The latter product is made by passing the smaller chips through a hammer mill, and in the past the trade demand has been for onion powder. At present, however, the call is for dried slices which, after rehydration, can be used in the same manner as freshly boiled onions. In the preparation of slices, considerable

amounts (under normal conditions up to about 25 per cent) of small chips are obtained which can be used for preparing powder. It is not considered advisable to attempt to dehydrate other vegetables in an onion-dehydrating plant. It is impossible to remove the odor of onions from the equipment and if other vegetables are then dehydrated these will almost certainly acquire an onion odor.

Varieties. It is necessary to start with an onion having a strong aroma and flavor. Mild varieties, when dried and reconstituted, have little flavor and are therefore worthless. The Ebenezer, White Portugal, Red Creole and White Creole are preferred. Other varieties, such as Early Yellow Globe, Mountain Danvers, Ohio Yellow Globe, Red Wethersfield, Southport Red, Yellow and White Globes, Brigham Yellow Globe and Yellow Globe Danvers are strong onions and may be used.* Sweet Spanish onions are too mild and are not suitable for dehydration, while the Australian Brown (also known as Oregon Brown or Buckskin) sometimes yields a bitter product.

Preparation. The vegetable should be thoroughly washed and cleaned to remove dirt. The outer paper-like layer and root base should be removed. Peeling may be done by hand, but some dehydrators use a flame peeler. Abrasive peeling can be used, but this causes a greater loss than the two methods previously mentioned, and is rarely used.

The peeled vegetables should be cut into slices about ¼″ thick and care should be taken to keep these slices intact. It is not considered advisable to hold the sliced material for longer than two hours before drying. Slicing should be carried out in a well-ventilated room, preferably provided with forced ventilation. If not well-ventilated, the atmosphere soon becomes unbearable.

Blanching. Onions are not blanched.

Peeling and trimming loss, when hand peeling is used, will vary from about 11 to 13 per cent; in flame-peeling, losses will be from 5 to 8 per cent.

Traying is at the rate of 1¼ to 1½ lbs per sq ft of drying area.

Drying temperatures should be such that at no time does the temperature of the product exceed 140° F, and it is preferable to

* For further details regarding onion varieties, the reader should consult "Descriptions and Types of Principal American Varieties of Onions," *U. S. Dept. Agr. Misc. Pub.* 435 (Sept. 1941).

use temperatures around 130 to 135° F. High drying temperatures cause a loss of pungency and yellowing of the material. Since such low temperatures are used, it is customary to finish drying in a bin.

Moisture content of the finished product should not exceed 4 per cent.

Yield will vary from 6 to 8 per cent, based on the weight of the fresh, unprepared material.

Peas

Dehydrated peas should not be confused with dried peas that are commonly used to make "split pea soup." To prepare dehydrated peas, immature sweet varieties are used.

The peas are vined as in regular cannery practice. Care should be taken to use peas that are sweet and tender and the majority of the pods should be well filled. The podded peas should be graded for size to facilitate more uniform drying.

Losses in podding will amount to from 55 to 60 per cent.

Blanching is preferably in boiling water for from 1 to 2 min. Since peas rapidly lose their sweetness after vining it is necessary to blanch promptly. Long blanching may cause the skins of mature peas to burst, and therefore this step in the process should be carefully executed.

Traying is at the rate of ¾ to 1 lb per sq ft of drying area.

Drying Temperature. At no time should the temperature of the product exceed 150° F. In the initial stages of drying, the relative humidity should be approximately 40 per cent to discourage case hardening.

Moisture content of the dried product should not exceed 5 per cent.

Yield. From 9 to 14 per cent, based on the weight of the fresh, unprepared material.

Peppers and Pimientoes

Chili peppers are dried in large quantities in the desert regions of the Southwest, by hanging in the sun. Several million pounds are also dehydrated annually in Southern California for use in flavoring Mexican dishes. Pimientoes (paprika) are dehydrated, and then powdered.

In general, chili peppers are dried in kilns at a temperature of

180° F. However, kiln drying is slow, and it is difficult to control the temperature and humidity. Cabinet or tunnel drying of peppers is a more satisfactory method.

In preparing peppers for drying, it is first necessary to remove any spray residue by means of an acid wash (p. 39).

Neither pimientoes nor peppers are blanched before drying.

After traying, the peppers are dried at a temperature not exceeding 150° F. At the start of the drying period, when the vegetable is still wet, temperatures as high as 180° F can be used, but the temperature of the product should at no time exceed 150° F, to prevent scorching. Peppers will darken if the relative humidity is too high, and therefore some dehydrators do not recirculate the air in order to keep the humidity as low as possible.

The moisture content should not exceed 5 per cent, and the dried product should be bright red in color and free from any browning or scorching.

Potatoes (Irish or White)

These are dried in the form of slices (for Lyonnaise potatoes), cubes (scalloped potatoes, stews etc.), strips (for Shoe string or French fried) and riced (for mashed potatoes).

Varieties. Potatoes suitable for drying should be mealy after being cooked by boiling, and tubers that become soggy or darken are not satisfactory. Irish Cobbler, Triumph, Green Mountain, Katahdin, Russet Burbank (also called Idaho Russet, Oregon Gem and Klamath Russet) Rural Russet, Rural New York No. 2, Early Ohio and Chippewa are suitable for drying. The water content of some of these may be high, and hence the yield of dry product will be low.

Preparation. The tubers should be thoroughly washed to remove dirt. If abrasive peelers are used, the potatoes should be sized to avoid excessive losses. When purchasing potatoes for dehydration, it is important to avoid irregular shaped tubers because these will give large losses in abrasive peeling. It is also desirable to avoid very small (less than 1½″ dia.) potatoes.

Flame-peeling or radiant-heat peeling is preferred to abrasive peeling because there is more loss in the latter process. In flame-peeling, the tubers are passed through a furnace lined with a refractory and the flames play directly upon them, charring the peels.

The furnaces may revolve and thus conduct the potatoes through the flames. The refractory in the furnace is so constructed that it can readily be replaced; this is generally necessary about once a year. Flame peelers are expensive and may run from $10,000 to $15,000, depending upon the capacity.

In radiant-heat peeling, the flame does not play directly upon the product, but radiant heat from the glowing refractory chars the skin of the potatoes. Radiant-peeling is superior to flame-peeling in that the former method also burns out most of the eyes, thus

Courtesy National Machine Works, Chicago, Ill.

FIG. 21. A flame peeler.

eliminating extensive subsequent trimming. Flame-peeling will not remove the eyes because the flame cannot reach the bottom of the cavity formed by the eye. In flame- or radiant-heat peeling, approximately 5½ gals of oil are required per ton of potatoes.

Inasmuch as the surface of the material obtained by both radiant-heat and flame-peeling is subjected to a temperature of between 2000 and 2200° F, the peel is charred. The charred peel is subsequently removed by powerful sprays of water (about 400 lbs pressure). It is of vital importance to remove the charred skin

immediately; otherwise the tubers will turn brown if allowed to stand. If it is impossible to wash immediately, the potatoes should be held in a 0.5 per cent solution of salt. They can be thus held for 24 hours without danger of browning, but the concentration of the salt solution is of utmost importance.

Potatoes can also be lye-peeled. For this, a 10 or 11 per cent solution of sodium hydroxide is used and maintained at a temperature of not less than 190° F. A treatment time of about 7 min is generally sufficient. After coming from the lye bath, the tubers should be washed with sprays of cold water which will remove the peels and excess lye. Losses in lye-peeling have been reported to be as high as 50 per cent, but it would seem that this is unusual. Mazzola [11] has perfected a new method of lye-peeling in which he claims losses of only 3 to 12 per cent are obtained. Mazzola uses high concentrations of sodium hydroxide, varying from 20 to 53 per cent. The strength of the lye bath and temperature and time of immersion are the three important factors for successful results.

Lye, abrasive and flame-peeling require subsequent trimming to remove eyes and discolored spots. It is necessary to trim carefully to remove these because they will show up in the dried material and render the product unsightly and possibly unsalable.

The trimmed potatoes are cut into slices from 3/16″ to 4/16″ thick; in cubes from 3/16″ to 6/16″ on a side; strips not less than 3/4″ in length and not less than 3/16″ or more than 6/16″ in either dimension.

Immediately after cutting into the desired shape, the material should be subjected to sprays of clean, cold water to wash away the surface starch. It is necessary to use strong sprays to obtain satisfactory results. If this operation is not properly executed, the material will stick together on the trays during drying. Operators usually install these sprays at the entrance end of the blancher.

If the prepared potatoes cannot be dried at once, they should be immersed in clean, cold water, or in a dilute (1 to 2 per cent) brine, but they must not be held in this manner for more than one hour.

Peeling and trimming losses will vary according to the method of preparation. When an abrasive peeler is used, losses will amount

[11] Mazzola, L. C., "New Caustic Peeling Method Reduces Waste and Saves Labor," *Food Ind.*, 15, No. 1, p. 53 (1943).

to from 17 to 25 per cent; with a flame- or radiant-heat peeler, losses will be about 10 per cent.

Blanching. The material is blanched in flowing steam at not less than 190° F for about 3 min, or until the pieces are translucent and peroxidase has been destroyed. Some dehydrators spray again with water after blanching, but the wisdom of this is questionable because of the danger of losing salts and water-soluble vitamins. If spraying is practiced after blanching, spray nozzles are installed at the exit end of the blancher.

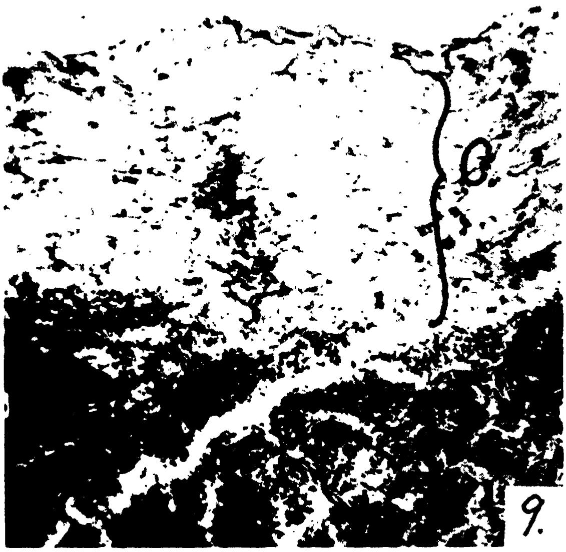

FIG. 22. Photomicrograph of a blanched potato slice. During dehydration, the outer cells (C) shrink more rapidly than the inner tissues. (From Reeve, "Dehydrated Vegetables Under the Microscope," U. S. Dept. of Agric. Pub.)

Traying. Strips are generally loaded at the rate of 1¼ lbs per sq ft; slices, ¾ to 1 lb, and dices at the rate of 1 to 1¼ lbs per sq ft. There should be a minimum of overlapping to avoid increase in drying time.

Drying temperatures should be such that the product never attains a temperature in excess of 150° F. However, in some instances temperatures lower than this may be necessary, particularly in tubers that have been stored and contain large amounts of sugar. In general, however, if a center-exhaust tunnel is used, a

dry-bulb temperature of 165° F and a wet-bulb temperature of 110° F at the wet (loading) end, and a dry-bulb temperature of 150° F and a wet-bulb temperature of 90° F at the dry (unloading) end will give a satisfactory product. Under these conditions, drying time will be about 5½ hours.

Moisture content of the dried product should not exceed 6 per cent. Potatoes that contain appreciably more moisture will darken perceptibly after three months' storage at 90° F.

Yield will vary from 13 to 20 per cent, based on the weight of the fresh, unprepared material.

Riced White Potatoes*

The method of preparation is identical with that followed with slices and strips insofar as washing and peeling are concerned. The peeled product is then thoroughly steamed and must be cooked through. To shorten the steaming time, large tubers may be cut in half or even in quarters. The exact time of steaming will depend upon the size of the potato. Proper steaming time can be judged by cutting one of the larger tubers and noting whether the cooking has penetrated to the center. If the center is uncooked, it will be of a lighter color than the cooked portions. Another method is to test for the destruction of peroxidase in a sample taken from the center of one of the larger tubers being steamed.

The cooked material is passed through a ricing device provided with holes not over ⅛″ in diameter. It is necessary to obtain a suitable ricer; otherwise the strings will stick together as they are extruded. Ricing is better accomplished when the tubers are still hot. An ordinary sausage grinder is not suitable for ricing, and spaghetti machines have also been found unsatisfactory. Most dehydrators construct their own machines, which they hold as trade secrets.

The riced material should be allowed to fall directly upon the drying trays, because any subsequent handling of the riced product will cause it to mat.

Drying temperatures of the riced product are the same as for slices, but drying is more rapid for the riced material. The moisture content of the dried product is the same as that for slices.

* By "riced" is meant the thoroughly cooked tuber which has been extruded in the form of strings and subsequently dehydrated.

Potato Powder

This may be made by either grinding and bolting the riced product, or by spray-drying a slurry of cooked potatoes. Potato powder is chiefly used for preparing souns.

Pumpkin and Squash [12]

Pumpkin is dried to be used primarily as a flour, but production is not great.

Varieties. Connecticut Field and Boston Marrow, Golden Cushaw, Winter Luxury, California Cheese are considered satisfactory, but the first two varieties are preferred.

Preparation. The vegetable is first washed to remove dirt. In some plants this is done by hand labor. The washed squash is then cut in two by hand with a broad-bladed knife, and the seeds and soft pulp are removed with a small scoop. The loss in seeds and pulp will amount to from 7 to 12 per cent. If from one variety, the seeds are cleaned and dried at temperatures not exceeding 120°F, and used for subsequent plantings. From 22 to 24 lbs of seeds will be obtained per ton of pumpkin.

The seeded pumpkins are next cut into small (about 1 to 1½ in) pieces, or they are sometimes shredded in a kraut or silage cutter. The finer the vegetable is cut, the more rapidly it can be dried.

Blanching is in steam for about 4 min. This sets the color; excessive blanching causes loss of weight and makes the product stick to the drying trays.

Traying is at the rate of 1 to 3 lbs per sq ft of drying area.

Drying. If a counter-current tunnel dryer is used, the temperature of the product should not exceed 160° F. Under these conditions, drying requires about 10 hours.

Moisture content of the dried product should not exceed 6 per cent.

Grinding and Bolting. The dried product is ground in a suitable mill and the ground material bolted to 70 to 80 mesh.

Yield. This will vary from 6 to 7 per cent, based on the weight of the fresh, unprepared vegetable.

[12] Christie, A. W., "Dehydrated Pumpkin Flour," *Am. Food, J.*, 17, 7 (1922).

Rutabagas

This vegetable is dehydrated in the form of slices, cubes or strips. The yellow variety is used.

Varieties. American Purple-Top and Golden Neckless (or Early Neckless) are generally used.

Preparation. The vegetable may be prepared in one of the following ways:

(a) The rutabagas are washed and then thoroughly cooked in steam for 30 to 35 min, depending upon the size. The cooked material is then trimmed, hand-peeled, and sliced into 3/16″ to 6/16″ slices; or in cubes 3/16″ to 6/16″ on a side; in strips not less than 3/4″ in length and not less than 3/16″ or more than 6/16″ square in cross-section.

(b) The washed vegetable is peeled in an abrasive peeler and then hand-trimmed. The trimmed material is then cut as described above. This method gives a greater peeling loss than the preceding, but less hand labor is involved. The cut material is blanched in flowing steam for about 4 min.

It is necessary to dehydrate the prepared material as soon as possible, and it is not desirable to hold it for more than an hour.

Peeling and trimming losses amount to from 8 to 15 per cent when abrasive peelers are used.

Traying is at the rate of about 1¼ lbs per sq ft of drying area.

Drying temperatures should be such that at no time does the temperature of the product exceed 160° F. There may be some trouble with darkening of the product. This usually takes place toward the end of the drying period when the moisture content has been reduced to less than 10 per cent.

Moisture content of the dried product should not exceed 5 per cent.

Yield will vary from 10 to 15 per cent, based on the weight of the fresh, unprepared vegetable.

Sweet Potatoes

These are dehydrated in the form of slices, cubes, strips and riced. The first three forms are blanched before drying; the last is cooked before dehydration.

Varieties. A great deal of research has been carried out by Caldwell, Moon and Culpepper [13] on varieties suitable for dehydration. It should be noted, however, that all these varieties were raised near Washington, D. C.

The work of Miller and Covington [13a] on the production of sweet potatoes of high carotene content will be of interest to dehydrators of this commodity. Miller and Covington found that the carotene content of the Puerto Rico variety of sweet potato increased rapidly during the first month of storage. There was a gradual decrease during the second month after which time there was a tendency for the carotene to remain constant. Although the carotene content of sweet potatoes may be materially changed by environmental factors and cultural practices, the most feasible means of increasing the carotene content is by hybridization.

The terms "sweet potato" and "yam" are quite often used interchangeably. "Yam" is a misnomer when applied to the Puerto Rico and other "moist"-fleshed sweet potatoes. Yams are a truly tropical species much different from sweet potatoes, and are not grown in this country. The term "moist"-flesh is also misleading because in reality these types contain less moisture than the so-called "dry"-flesh. Moist varieties and dry varieties are divided as follows:

Moist Varieties: Puerto Rico, Nancy Hall, Southern Queen.

Dry Varieties: Big Stem Jersey, Yellow Jersey, Maryland Golden, Vineland Bush, Orange Little Stem.

Sweet potatoes that have been stored for several months, but are sound and not diseased, do not yield a satisfactory product because they show dark streaks during blanching and drying. Contact with iron will also cause discoloration.

Preparation. It is necessary to use sound stock, and the vegetable should be thoroughly washed to remove dirt. If an abrasive peeler is used, the tubers should be steamed for about ten minutes before they are put through the peeler. Abrasive peeling results in rather heavy losses. Flame-peeling is satisfactory (p. 109), and the

[13] Caldwell, J. S., Moon, H. H., and Culpepper, C. W., "A Comparative Study of Suitability for Drying Purposes in Forty Varieties of the Sweetpotato," *U. S. Dept. Agr. Circ.* 499 (1938).

[13a] Miller, J. C., and Covington, H. M., "Some of the Factors Affecting the Carotene Content of Sweet Potatoes," *Am. Soc. for Hort. Sci.*, 40, 519 (1942).

tubers may also be hand-peeled where labor is sufficiently cheap to render this method economical. Some authorities recommend lye-peeling, and this may be accomplished by immersing the tubers in 2 per cent sodium hydroxide solution maintained at boiling temperature. The length of time in the bath will depend upon the variety and on whether or not the tubers have been stored. In general, a 10-min treatment is adequate. The potatoes should be immediately washed with strong sprays of cold water which will flush away the lye and remove the peels. Caldwell, Moon and Culpepper [13] studied the losses in peeling 39 strains and varieties of sweet potatoes with boiling lye or by abrasive peeling immediately after digging or after curing and storage. Their results indicated that the loss in abrasive peeling was directly related to the shape and size of the potatoes and especially to the degree of lobing and grooving present. If the sizes and shapes are irregular, it is better to use lye-peeling than abrasive peeling.

The peeled tubers should be cut into 3/16″ to 5/16″ slices; in cubes 3/16″ to 6/16″ on a side; or in strips not less than 3/4″ in length and with a cross-section of not less than 3/16″ or more than 6/16″ in either dimension. Immediately after slicing, the pieces should be thoroughly washed by strong sprays of clean, cold water to remove the starch from the cut surfaces. It is advisable to blanch immediately after washing, but if this is not possible, the material should be kept immersed in a 1 to 2 per cent salt solution. The tubers must not be held in this manner for more than one hour.

Peeling and Trimming Loss. With flame-peeling, this will amount to about 5 per cent; with lye-peeling, from 17 to 25 per cent; with abrasive peeling from 20 to 30 per cent.

Blanching is for about 6 min in flowing steam at 190° F, or until peroxidase is inactivated and the pieces are translucent. After blanching, drying of the product should be started immediately. It is not considered good practice to hold the blanched material for more than one hour before drying starts.

Traying is at the rate of not over 1¼ lbs per sq ft of drying area. If the tubers have been cut into slices, they will overlap at this loading rate, but drying will not be retarded.

Drying Temperatures. At no time should the temperature of the material exceed 165° F. In a counter-current dryer, the

humidity at the cool end should be about 25 per cent, and at the hot (dry) end about 12 to 15 per cent.

Moisture content of the finished product should not exceed 7 per cent.

Yield will vary from 20 to 30 per cent, based on the weight of the fresh, unprepared material, depending upon the variety.

Riced Sweet Potatoes

These are prepared in the same manner as riced white potatoes (p. 112).

Sweet Potato Powder

This may be obtained by:

(a) grinding and bolting the dried, riced material;

(b) drum-drying cooked, peeled potatoes reduced to a slurry.

The use of riced and powdered potatoes is limited because of the absence of a definite shape.

Other Vegetables

Vegetables other than those already mentioned are seldom dried commercially, and in many instances researches are still in progress to find the most favorable conditions for dehydration.

Chayote and **kohlrabi** are dried in the same manner as squash.

Mushrooms are being dried only experimentally in the United States, but their production in the Orient has been practiced for years. The dried product is quite likely to be tough and leathery, if improperly handled. Mrak and Cruess[8] advocate blanching before drying, but other authorities claim that this procedure renders the product too tough. It is necessary, in preparation, to discard the stems and merely use the buttons. The buttons may or may not be peeled, and drying is carried out at 150° F.

Sauerkraut is dehydrated by draining the liquid and dehydrating the kraut sufficiently so that when the acid liquor is returned to the dried material the moisture content of the product will not exceed 10 per cent. The liquid is not returned all at once, but gradually during the dehydration period. During dehydration, the temperature of the product should not exceed 145° F.

Squash. Hubbard squash is not dried because of the necessity and difficulty of removing the skin. Summer squash (and Zucchini)

may be dried, according to Mrak and Cruess[14] by trimming, washing and slicing into slices about ¼″ thick. The vegetable is not peeled and is steam-blanched for 6 to 8 min. Traying is at the rate of 1¼ lbs per sq ft of drying area. The material is dried at 150° F to a final moisture content of not more than 5 per cent.

Tomatoes are generally dehydrated on drum dryers. If the product is to be used as a soup, corn starch may be added to the product before drying to facilitate removal from the drums. Attempts have been made to spray dry tomatoes. In this case, the material to be dried must first be concentrated to about 18 per cent solids. If the solid content is less than this, the dried product is too gummy. It is also sometimes necessary to add small amounts of pectin (3 or 4 per cent of 100 grade, based on the weight of the total solids of the juice being dried) in order to obtain a finished product that is not too gummy. In general, dehydration of tomatoes may be said to be more or less experimental; some dehydrators, however, are producing commercial lots of dried tomato juice and soup.

Attempts have been made to dry whole or sliced tomatoes in a tunnel or cabinet dryer. This is not considered economically feasible.

Soup Mixtures

These are prepared by mixing various dehydrated vegetables and adding spices and monosodium glutamate. Formulas for three such soup mixtures are given below:

Dehydrated Vegetable Soup Mix

Soybean grits, debittered	5%
Portage barley No. 10	14%
Green peas	10%
Yellow peas	15.5%
Spaghetti or rice	12%
Tomato flakes (powdered)	15.85%
Tomato flakes	3%
Carrot flakes	3%
Onion flakes	5%
Parsley	0.5%
Sugar	6%
Salt	4%
Smoked salt	3%
Monosodium glutamate	3%
Black pepper	0.08%
Allspice	0.035%
Majoram	0.035%

[14] Mrak, E. M., and Cruess, W. V., "The Dehydration of Vegetables." *Special Subsistence Bull.* Quartermaster Corps, U. S. Army, 1941.

Chicken Soup Mix, Paste
25% by weight of chicken fat
75% by weight of seasoning

The seasoning may contain monosodium glutamate, but should not be in excess of 20 per cent by weight of the chicken soup mix paste. Soup is made from this mixture by adding one quart of boiling water to every ounce of the paste.

18% chicken fat
7% of a hydrogenated vegetable oil
75% seasoning

The seasoning can be monosodium glutamate in the proportions given in the formula for paste.

Soup powders may consist of precooked legumes with soybean flour, dry skim milk and condiments and the final product should not contain more than 9 per cent moisture. Such a soup powder may have the following composition:

Dry split peas	50%
Soybean flour (low fat)	25%
Dry skim milk	10%
Salt	7%
Monosodium glutamate	1%
Pepper	1%
Dehydrated powdered onions	4%
Dehydrated powdered tomatoes*	2%

*Dehydrated powdered celery may be substituted for the tomatoes.

Some soups of this type, especially if supplied for military needs, are fortified with yeast for the purpose of adding the vitamin B group. Navy beans may be substituted for the split peas in the above formula. Those contemplating preparing dried soups for the Army or Lend-Lease should familiarize themselves with the Army and Lend-Lease specifications. The former may be obtained from the Office of the Quartermaster General, Washington, D. C., and the latter from the Food Distribution Administration, U. S. Department of Agriculture, Washington, D. C.

Vegetable Tablets

The manufacture of these products is not great and their appeal is to a specialized trade. The majority of such tablets are made from spinach and are prepared by adding a small amount of agar, gelatin or gum acacia, or both, and stearic acid to powdered spinach so that it can be molded into tablets. The tablets are

then sugar-coated and colored with a certified dye. Each tablet contains about 0.4 gram (about 0.014 ounce) of spinach, and 0.2 gram of sugar coating. Apparently, such a tablet is to be used as a source of vitamin A, and since each tablet contains about 63 I.U. of vitamin A, a moderately active male adult weighing 70 kg (154 lbs) would have to consume about 80 tablets a day to obtain his minimum daily requirement of vitamin A, assuming that he did not obtain it from any other source.

Physical Changes Taking Place During the Dehydration of Vegetables

One of the conditions that may be encountered during the drying of potatoes and peas, but more especially in the drying of fruits, is "case hardening." This condition results when the outer tissues of the prepared material dry more rapidly than the inner and seal together during the early stages of drying. In the case of fruit, this condition is avoided by drying at high humidities. With vegetables, case hardening will not be bothersome if the pieces being dried are not more than 3/16″ in thickness.

Reeve [15] has carried out considerable research on the histology of vegetables during and after drying. In the case of carrots, blanching before dehydration results in a more uniform evaporation of moisture from the tissue; the cells are plasmolyzed and the cytoplasm denatured. Although it is generally believed that dehydration bursts the cells, Reeve has shown that this is not the case in the more common methods of drying.

When carrot slices are dried, the center (or core) of the carrot, which contains parenchyma tissue, does not show as much shrinkage as the outer cylinder, because the parenchyma tissue contains lignified xylem cells which act as a reinforcement to hold the surrounding cells in place. At the margin of the core, the xylem is arranged in radial rows, while the center of the core contains scattered xylem groups and thus shows slightly greater shrinkage. The initial outer shrinkage exerts a pulling force which is opposed to that of the internal shrinkage as drying progresses, and the pieces become T-shaped. At the peripheral regions of the slices, the force is greater at the corners than along the flat surfaces, thus

[15] Reeve, R. M., "Facts about Dehydration Revealed by Microscope," *Food Ind.*, 14, 51 (1942).

causing the slices to collapse along the flat surfaces. This is also the reason why diced vegetables, when dried, have the appearance of a cube with concave faces.

During drying, the cells on the surface of the carrot shrink and form a shell or case. This is not, however, true case hardening. But if development of a shell takes place more rapidly, as it will with increased temperature of drying, until the tissue is either completely dehydrated, or the shell provides a barrier to loss of moisture from the inner tissue, true case hardening has taken place.

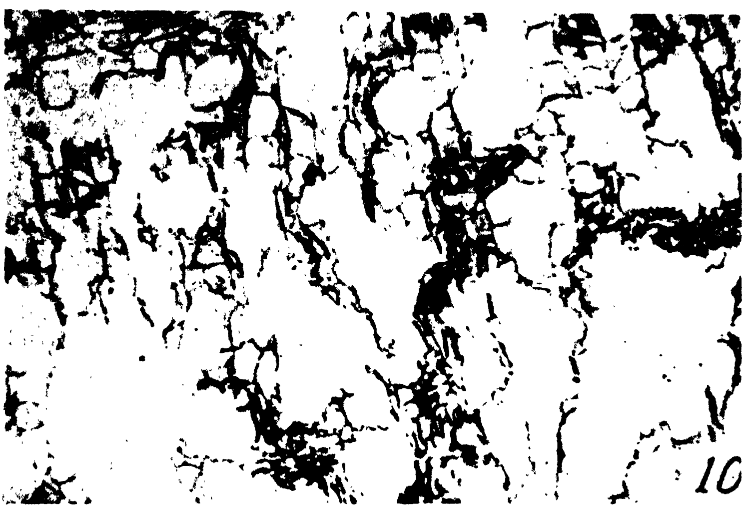

FIG. 23. Photomicrograph of dehydrated carrot tissue that had been frozen prior to dehydration. Note that the vegetable tissue has been ruptured by the ice crystals. (From Reeve, "Dehydrated Vegetables Under the Microscope," U. S. Dept. of Agric. Pub.)

In some instances when evaporation from the inner tissues is inhibited by the formation of shrunken cells, the moisture vaporized from the interior may produce sufficient internal pressure to rupture the softer tissues.

In the case of potatoes, blanching causes swelling or gelation of the starch grains. If dehydration is started immediately after blanching, the starch is in the gel state. On the other hand, if the potatoes have not been blanched, gelation of the starch does not occur until the wet-bulb temperature has reached about 150° F, a condition which will not occur during proper dehydration. Here the initial shrinkage of the surface layers of cells crowds the starch

grains together, and if shrinkage is too great, the cells may burst and release the starch grains. If this happens, such a product, when reconstituted, will be of a pasty or lumpy consistency. The chalky appearance of unblanched dehydrated potatoes is due to the intact starch grains which coat the surface. There may also be case hardening during the dehydration of unblanched potatoes, because the starch grains form a compact mass on the surface layers, thus inhibiting evaporation from the internal tissues.

In blanched potatoes, shrinkage of the cells is limited by the gelled starch, and during dehydration the vegetable develops a hard, glassy texture. This glassy texture is not so apparent in water-blanched tubers.

Blanched dehydrated beets appear to retain their color and aroma even without special storage precautions other than excluding moisture. Reeve [15] suggests that this may be caused by their high pectin content.

When dried beets are reconstituted, there may be considerable loss of color (bleeding), especially if too large a quantity of water is used. The pigment of the beet occurs in the cell sap; but when the beet is blanched and dried the cytoplasm of the cell is rendered insoluble and is no longer capable of selective permeability. The pigment thus readily diffuses out of the tissues when the dehydrated beet is put into water.

In preparing beets for dehydration, it will be noticed that they are cooked before slicing (p. 93). The reason for this is that if the raw beets were sliced and then blanched, the water-soluble pectins would leach from the tissues and tend to seal together any slices that might touch during drying.

Carrots contain a fatty oil, which according to Reeve,[15] occurs in the fresh tissues in a lipoprotein association. When carrots are blanched and dried, the lipoprotein association is broken and the oil is freed. Some of the carotene then dissolves in this oil, and this may be a factor in the keeping quality of dried carrots. As is well known, stored dried carrots quite often develop a violet odor brought about by a break-down of carotene. Preservation of carotene is believed to be affected by the amount of carotene dissolved in the oil, or protected by the film of oil, as well as the rate at which the oil oxidizes. If carrots are unblanched, they contain less oil-protected carotene and thus should lose carotene (as well

Table 30. Approximate Pounds Per Cubic Foot of Some Dehydrated Vegetables and Weight Per Shipping Ton (40 cu ft)*

Dried vegetable	lbs per cu ft	lbs per shipping ton
Beans, lima	26.2	1048
Beans, snap	12.5	500
Beets, slices	12 -15	480- 600
Cabbage, shreds	5.6 -7.5	225- 300
Carrots, cubes	20 -22	800- 880
Carrots, slices	3 -5	120- 200
Chard	5 -6	200- 240
Corn	26.6	1064
Kale	5 -6	200- 240
Mustard greens	5 -5.3	200- 210
Onions, slices	3 -5	120- 200
Peas	26.6	1064
Potatoes, white, slices	18 -21	720- 840
Potatoes, white, strips	23 -25	920-1000
Potatoes, white, cubes	23 -25	920-1000
Potatoes, white, riced	26 -28	1040-1120
Potatoes, sweet, sliced	17 -19	680- 760
Potatoes, sweet, riced	24.5-27.5	980-1100
Rutabagas, slices	7 -9	280- 360
Spinach	5.5-6.5	220- 260

*Not compressed. Volume of container not included.

as color) more rapidly than blanched carrots. This has been found to be the case. Dried, unblanched carrots, for instance, may lose 70 per cent of their carotene in three months' storage, while blanched, dried carrots stored under similar conditions lose but 10 per cent.

Some processes of dehydration are carried out at freezing tem-

Table 31. Trimming Losses and Yields of Some Dehydrated Vegetables.

Vegetable	Trimming Loss (%)	Yield, based on fresh, unprepared (%)	Moisture content of dehydrated vegetable (%)
Asparagus	50*	2- 3	5
Beans, lima	40-45	8-14	5
Beans, snap	8-13	8-12	5
Beets	30	7- 8	5
Cabbage	15-37	4- 7	4
Carrots	20-30	6-10	5
Celery	18-23	4- 8	4
Chard	47-55	4- 5	4
Corn	60-65	8-12	4
Kale	56-60	3- 5	4
Mustard greens	30-40	8- 9	4
Onions	11-13	6- 8	4
Peas, sweet	55-60	9-14	5
Potatoes, sweet	5-30	28-31	7
Potatoes, white	5-25	15-20	6
Pumpkin	7-12	6- 7	6
Rutabagas	8-15	10-15	5
Spinach	45-65	5- 6	4

*Tips.

peratures *in vacuo*. Such methods are alleged to be superior to ordinary dehydration in tunnel or cabinet dryers in that the former technique, being carried out under such low temperatures, will yield a product of better flavor and higher vitamin potency. Freezing, like cooking and drying under high temperatures, is a denaturing process. Freezing removes water from the cell contents by crystallization, while drying removes water by vaporization. When freezing is slow and at temperatures near the freezing point, large ice crystals form which will rupture the vegetable tissues. In Fig. 23 is shown a section of carrot tissue that had been frozen and then vacuum-dried. In general, vegetables dried by this method are porous because cell shrinkage is not so pronounced as in vegetables dried by heat.

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Chapter 4

Dehydration of Eggs, Milk and Butter

According to Termohlen, Warren and Warren,[1] Charles A. La Mont[2] was probably the first inventor of a process for drying eggs, although he did not start operating a plant until 13 years after he had taken out his patent (1865). W. O. Stoddard also operated an egg-drying plant located in St. Louis, Mo., at about the same time that La Mont started in this field. There was considerable optimism about this new method of preserving eggs and the great saving in shipping space, but the industry did not seem to expand until the period extending from 1895 to 1905. In the early days after passage of the first Federal Food and Drug Act there appears to have been some difficulties with Governmental regulatory agencies, which claimed that the products being turned out were not all that they should be. Thus, certain firms were accused of resorting to formaldehyde to mask the odor of rotten eggs used in drying, and there were several Notices of Judgment by the U. S. Department of Agriculture between 1909 and 1910 for cases coming within the Food and Drug Act. Seizures under this act continued until 1914. By 1915, the egg-drying industry in the United States had started to decline. However, this was not solely because of the seizures or regulatory actions cited above, but because the price of eggs and labor rose sharply, and because the opening of the Panama Canal permitted cheaper Chinese egg products to be shipped to the Atlantic seaboard.

The dried egg industry lay dormant in the United States while German engineers started the expansion of the industry in the Orient. To combat this, attempts were made to dry eggs in the United States by using equipment designed for milk drying, with the idea of reducing labor costs. This attempt was unsuccessful because of unfavorable price relationships and increasing imports

[1] Termohlen, W. D., Warren, E. L., and Warren, C. C., "The Egg-Drying Industry in the United States," *U.S. Dept. Agr., Marketing Inf. Series.* PSM-1 (1938).

[2] La Mont, C. A., U. S. Pat. 51,263 (1865).

of dried and frozen eggs from China. In 1922 a tariff was put on both imported dried and frozen eggs, and although imports slumped the products were still too cheap for domestic competition.

It was not until 1927, when China was torn by a civil war, that egg-drying operations in the United States were again attempted on a commercial scale. Favored by another increase in tariff in 1931, the industry expanded until about 1936. Since the outbreak

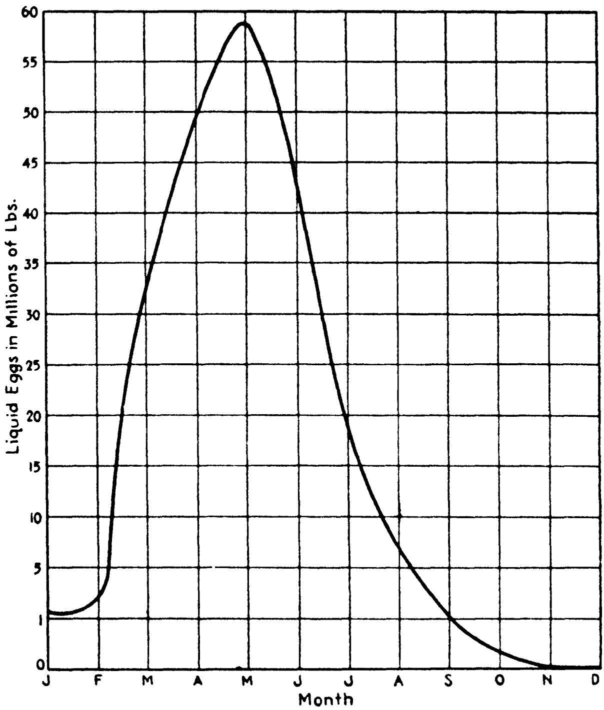


FIG. 24. Production of liquid eggs during different months of the year 1940. (Data from "Agricultural Statistics," 1941, U. S. Dept. Agric.)

of the Second World War, production of dried eggs has been considerably increased, and they are now being prepared at the rate of about 400,000,000 pounds a year.

Normally, eggs are dried when they can be purchased in large quantities at low prices. Since nearly one-half of the total egg production of the United States occurs in March, April, May and June, these are the months in which egg products are dried. However, under present war conditions, this does not necessarily hold true, and eggs are dried in every month of the year.

Washing. The eggs are first washed, the usual method employed in the Middle West being a hand operation. This is not considered very satisfactory. On the Pacific Coast, eggs are washed by either wet or dry sand-blasting. In wet sand-blasting, a phenol compound is used with the water to prevent subsequent rot. Broken and cracked eggs should be kept separate from uncracked eggs to prevent spoiling of the sound material.

Courtesy U. S. Dept. of Agriculture. (Photograph by Forsythe)

FIG. 25. The first step in the egg-drying process is a thorough washing of the eggs brought in to the drying plant. Each egg gets an individual scrubbing, necessary for a clean and wholesome product.

Candling. Before the eggs are broken, it is necessary to determine their quality. This is accomplished by candling where each egg is examined separately in a darkened room with an "egg candle." (Fig. 26). This is a device that permits rays of light to pass through an egg and thus the appearance of the yolk and white can be ascertained. Candling is not an exact science, but the aim is to separate the eggs into classes which indicate the quality one may expect after they are broken.

In practice, the candler takes two eggs in each hand and pro-

ceeds, according to a description in *U. S. Dept. Agr. Circ.* 583,[3] as follows: "One egg is held with the large end up and in an inclined position before the opening in the candling device. While held in this position, the egg is given a quick twist or turn on its long axis. This sets the yolk in motion and permits the appearance and behavior of the yolk to be noted. After one of the eggs in hand is examined, an egg in the other hand is placed before the candle, and in the meantime the position of the two eggs held in the first hand is reversed. In this way, the eggs are alternated before the

Courtesy: Extension Service U. S. Dept. of Agriculture

FIG. 26. Candling and grading eggs in a humidified egg room in a packing house.

candle until all have been examined and their quality determined."

As the eggs are candled and graded, they are usually placed in 12-quart galvanized iron pails (keeping cracked eggs separate from sound ones) and carried to the breaking tables. If the whites are to be separated from yolks, the eggs are generally chilled to facilitate better separation. At the present time, very few yolks and whites are separated because the demand is for whole dried eggs.

Unusual Appearance of Eggs While Candling. "Tremulous" air cell is caused by jars and shocks in handling and shipping. In this condition, the shell membrane becomes separated and permits

[3] Anon., "Eggs and Egg Products," *U. S. Dept. Agr. Circ.* 583 (1941).

a tremulous movement of the air cell as the egg is rotated before the candling machine.

Yolk is at the large end of the egg or shell and shell membrane. This may mean a deterioration in the quality of the egg. Normally, the yolk is at the center of the egg, but as it deteriorates the yolk tends to approach the shell.

Dark areas in the yolk may be due to germ development. If large, such eggs are classed as inedible.

Blood rings are caused by death of the developing embryo, resulting in a gathering of rings of blood about the germ spot. Such eggs are inedible.

Dark spots in the white are caused by foreign matter, but their presence does not necessarily render the egg inedible.

Greenish color of whites or yolks is detected when the eggs are broken. The color is caused by too much green vegetation in the feed of the hens. Such eggs are placed in the lowest class of edible eggs.

Breaking and Separation. This is accomplished by hand labor (women), since no satisfactory machine has ever been devised which will also smell the broken-out eggs and reject them if not satisfactory. The eggs are broken against a blunt knife mounted above a small tray which is provided with two to four cups each of which is capable of holding the yolks and whites of about three eggs. The operator breaks three eggs into the cup and then smells the material, and if fresh the contents are poured into a pail beside the operator. If the material is found to be imperfect, the eggs are discarded into large cans or onto a conveyor that removes the material from the plant. Defective eggs, not deemed suitable for human consumption, are used for industrial purposes. One bad egg, if used, can act as a starter for infecting an entire batch of broken-out clean eggs. If by accident, defective material has been mixed with sound stock, the entire batch should be discarded and all equipment thoroughly cleaned and then sterilized with steam.

In cases where yolks and whites are kept separate, a special breaking device is necessary. A sliding hinged separator is attached to the breaking knife. This separator has a receptacle about the size of an egg, and a ring with a sharp edge. The latter is just large enough to fit over the yolk, and serves to cut the yolk from the white as the egg rests in the receptacle (Fig. 28). As the

whites are cut from the yolk, they fall into a cup and the receptacle is tipped so that the yolk will fall into another cup. The separation of yolk and white is not absolutely clean-cut, and in some instances the white will retain residual yolk. If the vitellin membrane is weakened or ruptured, separation is impossible. As the

Courtesy U. S. Dept. of Agriculture. (Photograph by Forsythe)

FIG. 27. In the breaking room of the egg-drying plant operators quickly crack each egg on a breaking bar and drop the contents into a cup. When there are three eggs in a cup, the operator smells of them to determine whether or not any bad ones have been broken into the cup. If the smell test reveals the presence of no bad ones, she dumps the contents of the cup into a large container. If bad ones are present, she dumps the contents into a waste container.

whites and yolks are separated, they are inspected for odor and appearance.

Churning of Eggs. Whole eggs and yolks, after breaking, are lumpy, and it is necessary to crush the yolk skins and to remove particles of shell. This is usually accomplished by churning in a

Table 32. Approximate Chemical

Shell and membrane 10%	Water	1.46%		
	Organic matter	4.2%		
	Ash	55.33%		
	Calcium	37.8%		
	Phosphorus	0.2%		
	Magnesium	0.4%		
	Pigments { oörhodein, oöcyan			
	Undetermined	39.01%		
White 58%	Water	86%		
	Protein	11.6%	Albumen	69.7%
			Conalbumen	9.0%
			Globulin	6.7%
			Mucoid	12.7%
			Mucin	1.9%
	Fat	0.2%		
	Nitrogen-free extract	0.8%		
	Glucose	0.4%		
	Ash	0.8%		
	Potassium	0.15%		
	Sodium	0.16%		
	Magnesium	0.011%		
	Calcium	0.006%		
	Iron	0.0072%		
	Sulfur	0.2%		
	Phosphorus	0.59%		
	Pigments (d-riboflavin)			
	Vitamins { Riboflavin, 60—120 Sherman-Bourquin Units per 100 g.			
	Minor constituents: aluminum, manganese, zinc, copper, lead, fluorine, iodine and silicon.			

mixing tank and then screening and settling. Egg whites cannot be churned because of excessive foaming, and they are therefore forced through fine screens which break down the fibrous structure and remove particles of shell.

Treatment of Albumen. The albumen of eggs consists of two portions, known as the thick white and the thin white. Only the thin white possesses proper whipping qualities and it is therefore necessary to reduce the thick white to the consistency of the thin. In commercial practice, this is carried out by fermentation, which should be so controlled as to remove the carbohydrates in the whites without digesting the protein.

The whites, prepared as described above, are placed in tanks where the fermentation process takes place. Temperature of fermentation should preferably be 86° F and should be completed

Composition of Eggs

Yolk 32%

Water	49%		
Protein	6.7%	Vitellin	78%
		Livetin	21%
Fat	31.6%		
Nitrogen-free extract	1.2%		
Dextrose	0.21%		
Ash	1.5%		
Potassium	0.113%		
Sodium	0.049%		
Magnesium	0.017%		
Calcium	0.147%		
Iron	0.0072%		
Sulfur	0.2%		
Phosphorus	0.59%		
Chlorine	0.17%		

Pigments:
- Xanthophyll
- Zeoxanthin
- Cryptoxanthin
- Capsanthin (occasionally)
- Carotene (very small amount)

Vitamins:
- Vitamin A: 840—8400 I. U. per 100 g.
- Riboflavin 150—300 Sherman-Bourquin Units per 100 g.
- Niacin present
- Thiamin 120 I. U. per 100 g.
- Vitamin K
- Vitamin E
- Vitamin D (depending on diet of hen)

Minor constituents: aluminum, manganese, zinc, copper, lead, fluorine, iodine, silicon.

in 72 hours. If fermentation is prolonged, there is a loss of acid, and objectionable odors develop.

According to Stuart and Goresline,[4] during fermentation there is a rapid increase in pH of the white from 7.45 to 9.10 within the first 12 hours. Stewart and Kline,[5] however, present data showing a decrease in pH for about the first 45 hours, and then an increase. Stuart and Goresline explain the increase found in their researches as due to the breakdown of the buffer system through loss of carbon dioxide. After 72 hours, according to these workers, the pH drops from 9.10 to 6.25. These latter data follow those of Stewart and Kline. From Fig. 29 it will be seen that there is a close relationship between loss of dextrose and acid formation.

[4] Stuart, L. S., and Goresline, H. E., "Bacteriological Studies on the 'Natural' Fermentation Process of Preparing Egg White for Drying," *J. Bact.*, **44**, 541 (1942).

[5] Stewart, G. F., and Kline, R. W., "Dried-Egg Albumen. I. Solubility and Color Denaturation," *Proc. Inst. Food Techn.*, 1941, p. 48.

During the first 72 hours of fermentation there is no apparent breakdown of egg-white proteins. At 96 hours, Stuart and Goresline[4] found an increase in combined amide and amino nitrogen value.

Courtesy U. S. Dept. of Agriculture. (Photograph by Forsythe)

FIG. 28. When albumen is dried, the yolks are separated from the whites by using the arrangement shown in the figure. Tilting the separator sends the yolk into another cup.

At the start of the fermentation, the white separates into two phases: thin white and thick white. The thin white accumulates at the bottom of the tank, while the thick white gradually rises as the pH decreases. All of the mucin, along with some mucoids,

accumulates on the surface as a scum. This scum is removed before drying. The bacteria present are usually of the genera *Aerobacter* and *Escherichia.* The presence of *Proteus, Serrata* and *Pseudomonas* will yield a dull, dingy and amorphous product upon drying.[4] Stewart and Kline [5] state that during their experimental fermentations, the bacteria count of the product rose from less than one thousand per gram, to two hundred million per gram.

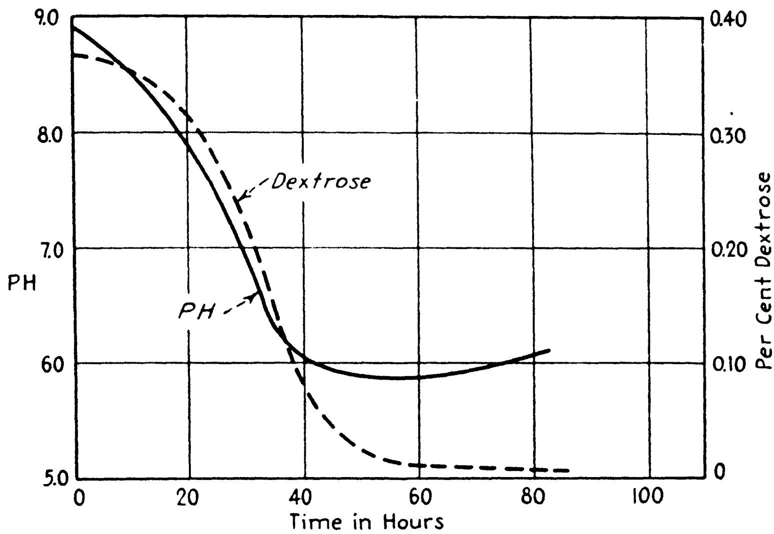


FIG. 29. Changes in pH and dextrose during the fermentation of egg albumen. (From Stewart and Kline: *Proc. Inst. Food Technologists,* 1941.)

At the end of 72 hours, when fermentation should be completed, the foam at the top of the tank is skimmed off and the liquid drawn off to within about 3 inches of the bottom. Material from both separations, which amounts to from 5 to 8 per cent, is not considered suitable for drying and thus constitutes a loss. It is claimed [6] that the foam may be recovered and dried by adding, with constant stirring, 2 quarts of 20 per cent citric acid to every 50 gals of foam. Into the acidified foam is then stirred 5 grams of dried pepsin dissolved in one pint of the citric acid solution. When liquefaction is complete (usually in 4 to 5 hours), the batch is neutralized with ammonia in the usual manner. This technique is not at present being used commercially.

[4] Anon., "Information on Drying Eggs," *Food Res. Div. Mimeo.* MC-33 *Bur. Agr. Chem. & Eng.,* U. S. Dept. Agr., 1938.

To check further fermentation, about 2 ounces of ammonia water and 3 ounces of ethyl alcohol per 100 pounds of albumen are stirred into the batch. This is in accordance with the Chinese practice, but not all American producers add ammonia and alcohol.

Another method for preparing albumen for drying is by tryptic digest.[7] In this method the albumen is thinned faster than by natural fermentation and repulsive odors are eliminated. Balls and Swenson [8] point out, however, the instability of dry egg albumen produced in this manner.

Mulvany [9] describes his process for treating albumen, in which the albumen is acidified to about pH 5.8 and then agitated in a vacuum at an elevated temperature close to the coagulating point.[10] It is claimed that the resulting spray-dried product has a low bacteria count, no odor other than that characteristic of eggs, and is of excellent keeping quality.

In spite of many attempts to find methods other than fermentation to prepare egg albumen for dehydration, the industry still adheres to the fermentation method. It is considered a necessary step in the production of an albumen of permanent stability in the dry state because it removes the dextrose from the product.

Drying of Egg Albumen. This is usually accomplished in steam-heated cabinet or tunnel dryers of a type similar to those described in Chapter 1. The fermented albumen is spread on shallow pans or trays of aluminum or some of its alloys. The pans are given a thin coating of Vaseline or neutral mineral oil to prevent the dried product from sticking. The initial drying temperature is about 120° F and this is maintained for 18 hours. During the next 40 to 45 hours, the temperature is raised to 140° F. At the end of this time, the material is removed from the dryer and placed on tables or wire meshes to cool for about 24 hours before it is broken into flakes for packing. Or the product may be put into a "finisher," a cabinet maintained at 100 to 110° F. It requires from 2 to 3 hours to finish the product in these cabinets.

[7] Balls, A. K., and Swenson, T. L., "Process for the Alteration of Egg White," U. S. Pat. 2,062,387 (1936); U. S. Pat. 2,054,213 (1936).

[8] Balls, A. K., and Swenson, T. L., "Dried Egg White," *Food Res.*, 1, 319 (1936).

[9] Mulvany, H. A., "How Eggs are Dried—Methods and Standards," *Food Ind.*, Dec., 1941.

[10] McCharles, C. H., and Mulvany, H. A., "Method of Treating Egg Whites to Improve Keeping and Whipping Qualities," U. S. Pat. 2,087,985 (1937).

The dried albumen obtained is known as *flake* or *crystalline* albumen. It is not truly crystalline, but because of its sheen and sparkle it appears to possess a crystalline structure. *Powdered albumen* is prepared by grinding and screening the crystalline product.

Egg albumen cannot be readily spray-dried because it is too viscous and because, for reasons as yet not fully understood, spray-drying decreases the solubility of the product. There is also considerable loss because it has not been found possible to recover all the entrained albumen in the exhaust air from the dryers.

Yields. While the proportion of albumen to yolk will vary according to the quality of the egg and the care exercised in separating the yolk from the albumen, 100 pounds of liquid eggs will yield about 13.7 lbs of dried albumen.

Moisture content of the dried product should be from 7 to 12 per cent.

Grades of Dried Egg Albumen

The Egg Products Association of America, Inc. give the following Standards of Quality for Albumen (quoted by Termohlen, Warren and Warren)

1. Fancy hen (chicken) albumen crystals:
   Appearance: Bright clear crystals
   Siftings: Not to exceed 20 per cent
   Odor: No objectionable odor
   Beating: Beat 90 to 100 per cent with good consistency, minimum 6¼ inch after leveling*.

2. Prime hen (chicken) albumen crystals:
   Appearance: Bright clear crystals
   Siftings: Not to exceed 20 per cent
   Odor: No objectionable odor
   Beating: Beat 80 to 100 per cent with good consistency, minimum 5¾ inch after leveling.

3. Fair hen (chicken) albumen crystals:
   Appearance: Fairly clear crystals.
   Siftings: Not to exceed 20 per cent
   Odor: Slight odor permissible
   Beating: Beat 70 to 85 per cent with fair consistency, minimum 5¼ inch after leveling.

4. Poor hen (chicken) albumen crystals:
   Appearance: Unimportant
   Siftings: Not to exceed 20 per cent
   Odor: Unimportant
   Beating: Beat 50 to 70 per cent with fair consistency, minimum 4¾ inch after leveling.

*See page 269.

5. Nonbeating hen (chicken) albumen crystals:
   Appearance: Unimportant
   Siftings: Not to exceed 20 per cent
   Odor: Unimportant
   Beating: No test necessary.
6. Chicken albumen siftings, duck albumen, and duck albumen siftings to be sold under the same description.

Drying Whole Eggs

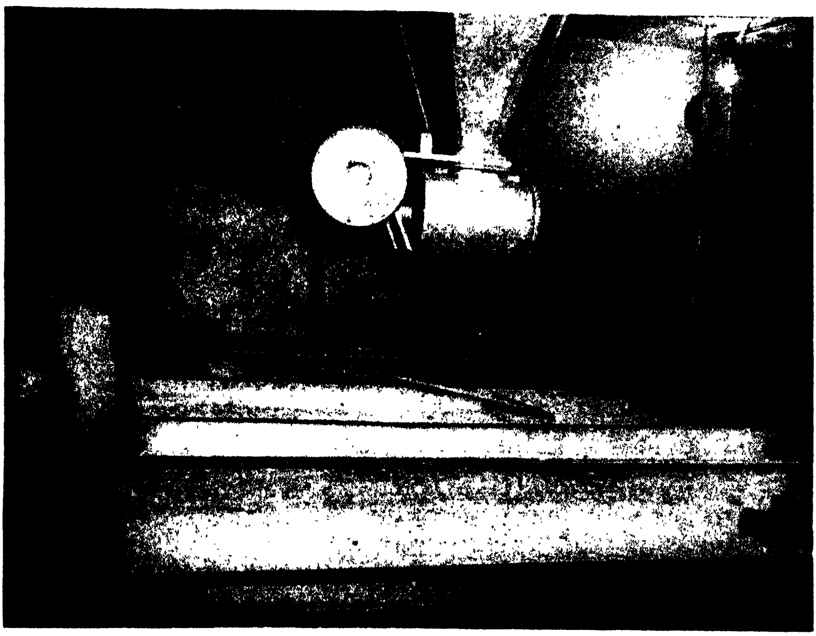
These are generally prepared by spray-drying, although there is a limited production of pan-dried whole egg, which yields flakes instead of a powder. At one time, especially during the First World War, eggs were dried on a belt (usually of aluminum) travelling through a tunnel through which air at 140° F was circulated. It generally required about 2 hours for the first drying. The product was then placed on trays and finished in a cabinet dryer at 100-110° F. This final drying required about 2½ hours. At present, practically no dried eggs are produced by this method.

Two types of spray dryers are used: the tunnel or chamber type, and the cyclone type. In the former, the air passes through a filter to a suitable fan which delivers the filtered air through heating coils to the drying chamber. Some spray dryers may be heated by direct fire rather than by steam coils. In the drying chamber, the hot air comes in contact with the atomized eggs pumped into the chamber under pressures of from 1500 to 6000 lbs per sq in. The eggs are immediately dried and drop to the floor as a powder. In some instances, the powder is allowed to accumulate to a depth of about 4 inches and is then removed by shovels. Other dryers are self-cleaning. As the material comes from the dryer, it is quite hot (the temperature within the chamber varies from about 160 to 220° F) and may stick together. To prevent this, the dried eggs are conducted to a rotary spiral conveyor to cool and to mix the product, which is finally conducted to a shaking screen from which it falls into barrels.

The chamber dryer must be provided with a dust-collecting system. This is generally another chamber consisting of a series of screens or cloth bags, and connected by a duct with the drying chamber proper. About 1 sq ft of screen or bag surface should be provided for every cubic foot of air handled. An exhaust fan in the drying chamber exhausts the air into the dust-collecting system. As the powder builds up on the screens or bags, the static pressure

in the drying chamber will increase and it is necessary to remove the dust from the screens. This is usually carried out by an automatic tapping device. In small dryers, the tapping is done by hand. In general, in a chamber type dryer, only about 25 per cent of the egg powder reaches the dust collectors.

In the cyclone type of spray dryer, the air delivery system does not differ to an appreciable extent from that of the chamber type. There is a saving of floor space with the cyclone type, but it usually



Courtesy U. S. Dept. of Agriculture. (Photograph by Forsythe)

FIG. 30. Spreading dried egg blown down out of the dryer. This cools the product for packing in the barrels in which it is shipped.

requires two or more stories to house a cyclone drying plant. When eggs are dried in a cyclone dryer, the dried material is carried by centrifugal force to the sides of the dryer. The drying chamber itself is arranged in the form of a cone (Fig. 33) and the dried material, following a spiral course, is discharged through an opening in the conical bottom. Many of these dryers have a long blade, or a series of chain links, which revolves in the drying chamber and removes the egg particles from the side walls. If it is not so equipped, it is necessary to stop the dryer at the end of each day's

operation and thoroughly clean the chamber. The cyclone dryer must also be provided with a dust-collecting system.

Spray dryers are provided with varying types of spray nozzles, but each type is so arranged as to distribute the finely divided particles over as large an area as possible. Distribution should, of course, be so controlled that the spray does not strike the walls of the dryer. The nozzle used for eggs may consist of a single hole (about the size of that obtained with a No. 72 drill, 0.0280″) or of a hole and a whirling attachment, such as a cup, at the base of which is located the spray nozzle. The nozzle should be so constructed that the part containing the hole can be easily replaced, because egg products pumped through at high pressures rapidly cut away the hole, thus enlarging it. Because of the tendency of mechanical trouble from high-pressure pumps, there has been a tendency to replace spray nozzles with a spinning disk. These disks are rotated at very high speeds, and the liquid eggs dropping in a fine stream upon the disk are broken into a fine spray. These disks appear to give less mechanical trouble than high-pressure pumps which are necessary when spray nozzles are used alone.

Drying of Yolks

This is carried out in the same manner as whole eggs. Some dehydrators add sufficient water to the yolk to thin it prior to drying, in order to get a better spray. The economy of such a procedure would be deemed questionable.

Grades of Dried Whole Eggs and Dried Yolks

Standards of quality for these two products as set forth by the Egg Products Association of America Inc. are given below (quoted by Termohlen, Warren and Warren):

1. Prime spray hen (chicken) egg yolk:
   Taste: Sweet and wholesome.
   Texture: Smooth and velvety.
   Solubility: Good.
   Color: Good bright yellow appearance.

2. No. 2 spray hen (chicken) egg yolk:
   Same requirements as prime except color is not guaranteed.

3. Summer cargo spray hen (chicken) egg yolk:
   Same as No. 2 quality, but "Summer Cargo" must be mentioned.

4. Prime granular hen (chicken) egg yolk:
   Taste: Sweet and wholesome.
   Color: Bright deep yellow, as nearly uniform as possible.
5. No. 2 granular hen (chicken) egg yolk:
   Taste: Sweet and wholesome.
   Color: Not guaranteed.
6. Prime spray whole hen (chicken) egg:
   Taste: Sweet and wholesome.
   Texture: Smooth and velvety.
   Color: Good.
   Albumen: Contents about 33 per cent on dry basis.
7. No. 2 spray whole hen (chicken) egg:
   Taste: Sweet and wholesome.
   Texture: Smooth and velvety.
   Color: Not guaranteed.
   Albumen: Contents about 33 per cent on dry basis.

The moisture content of dried yolks and whole eggs should not exceed 6 per cent.

Table 33. Conversion Factors of Dried Egg Products from Whole Eggs*.
(*Termohlen, et al.*)

Products	Yield of liquid eggs in 1 case (30 doz) of shell eggs	Yield of 1 doz shell eggs		Requirements for 1 lb of dried egg products		Yield of product from	
		liquid	dried	liquid	shell	100 lbs liquid	30 doz shell
	(lbs)	(lbs)	(lbs)	(lbs)	(doz)		
Whole egg	35.00	1.1667	0.3268	3.57	3.06	28.01	9.804
Albumen	19.25	.6417	.0879	7.30	11.38	13.70	2.637
Yolk	15.75	.5250	.2386	2.20	4.19	45.45	7.158

*Shell eggs consist of 45 per cent yolk and 55 per cent albumen. One pound of dried whole egg contains 0.731 lb of dried yolk and 0.269 lb of dried albumen. A case of 30 dozen eggs weighs about 42 to 43 lbs net.

Table 33 gives conversion factors of dried egg products from whole eggs. However, in using this table, it should be borne in mind that shell eggs vary greatly in size and quality and that these factors will affect the yield obtained.

Table 34. Composition of Dried Egg Whites and Yolks.

(*From Grant: "Confectioners' Raw Materials: their Sources, Modes of Preparation, Chemical Composition, and the Chief Impurities and Adulterations," Longmans, Green Co. Ltd. 1911*).

Constituent	Whites (%)	Yolks (%)
Water	12.57	5.02
Proteins	78.75	34.92
Fats	4.31	53.35
Ash	4.24	3.69
Other	0.13	3.00
	100.00	100.00

Pidan (Houeidan, Dsaouidan)

This is a Chinese product made from fresh duck eggs. A mixture of 5 parts of sodium carbonate, 25 parts of ashes from burnt straw, 4 parts of sodium chloride, 40 parts of slaked lime and 26 parts of water are made into a paste. Each egg is coated with this mixture to obtain a layer about one-quarter of an inch thick. In order to prevent the eggs from sticking together when they are stored, they are covered with rice husks. The eggs thus prepared are placed in earthenware jars, sealed with wet clay and allowed to stand for about a month. During storage, there is a partial dehydration, and both white and yolk are coagulated, the former turning a dark brown and the latter a greenish gray with concentric rings of gray. Since there is a partial decomposition of the proteins and phospholipids, and an increase in ash (probably due to the alkaline covering), the eggs have an ammoniacal taste described as caustic or cheesy.

Dry Milk

The art of drying milk is old, and probably dates back to 1289 when Marco Polo described a method used by the Tartars. Modern development of the dry-milk industry has been connected with that of the condensed-milk industry; the difference between the two products lies only in the degree of concentration. The results obtained in early attempts to dry milk were quite disappointing because the methods used were crude and the product obtained left much to be desired from the standpoint of both keeping qualities and solubility.

About 1810, Appert obtained milk tablets by producing a pasty mass obtained by slowly concentrating milk agitated by a current of dry air.[11] In 1855, Grimwade secured a British patent for drying milk by adding sodium or potassium carbonate to the milk, evaporating with constant stirring until a doughy mass was obtained, and then adding cane sugar. The doughy mass was then pressed between rollers and flattened into thin ribbons which were subsequently dried and powdered. The resulting product was granular because of the presence of cane sugar. In 1853, Borden filed his patent for drying milk, but this patent was not registered until 1856, one year after Grimwade had obtained the patent on his process.

[16] Porcher, C., "Dry Milk," p. 85, Olsen Publishing Co., Milwaukee, Wis., 1929.

Many methods have been devised for drying milk and these will be briefly discussed. Only a few survive for present industrial application in the United States.

Wimmer Process. Milk is concentrated during mechanical agitation in a jacketed vacuum pan until the water content has been reduced to about 30 per cent. The vacuum is then released and drying continued in the open air.

Campbell Process. Milk is concentrated to a pasty consistency in open jacketed pans, while being agitated with a stream of warm air. The pasty mass obtained is placed on screens and dried in cabinet dryers at a temperature below the coagulating point of the albumen.

Grimwade Process. This has been outlined above.

Ekenberg Process. A revolving steam-heated nickel drum is inclosed in a large drying chamber to which a vacuum is applied. The lower part of the chamber holds sufficient milk so that the revolving drum dips into the liquid, a film of which adheres to the drum. This film is partially dried when the drum has made one revolution and is removed by knives or scrapers. Drying is carried out between 98 and 100° F. After removal from the drums, the milk is placed in a special drying chamber at 90° F for about one hour.

Passburg Process is similar to the Ekenberg process, but in the former the thickness of the milk film on the drum is regulated.

Gover Process. This is similar to both the Ekenberg and Passburg processes with the exception that two counter-revolving drums, heated by water at a temperature below 212° F, are used. Only a partial vacuum is maintained and drying is carried out at about 160° F.

"Buflovak" Process. This process also involves the use of drums, drying being carried out in a vacuum at a low temperature. It differs from previous drum processes in the manner of feeding the milk to the drums. The milk is held in a reservoir situated at the bottom of the vacuum chamber, and is pumped to a shallow pan below and close to the revolving drum. A slight pressure is maintained on this pan and this pressure tends to force the milk against the drum, thus giving a uniform film. The dried milk is removed by means of a knife, the product falling into a spiral conveyor. Loss of any milk dust is prevented by a liquid-sealed collector connected to the vacuum chamber.

Just Process. Two drums are used revolving at 18 to 20 rpm in opposite directions and spaced from 0.04″ to 0.05″ apart. The temperature of the heating surface of the drums lies between 212 and 270° F. A vacuum is not used. Milk is constantly fed between the two drums and forms a pool there, which serves as a means of partial concentration. In the original Just patent, small additions of lime and calcium chloride were called for to reduce the acidity of the milk. Calcium or sodium hypochlorite was also added to preserve the fat in the dried product. The Just process was later modified as the Just-Hatmaker Process, and is the most widely used drum process today. Steam pressures on the drums vary from below 40 lbs (286° F) to as high as 100 lbs (337.9° F). At the lower pressures, revolution of the drum is about 12 rpm, while at the higher pressures it is about 20 rpm. To increase the capacity of the drums, the milk is generally heated to 185° F before applying.

James Bell Process is similar to the Just Process and about 1936 it was used extensively in Australia.[12] It differs from the Just Process in the manner of handling the steam from the drums. A gear-driven pump returns to the boilers the high pressure steam from the drums, and no steam traps are utilized.

Mignot-Pluney Process (also called Mynot-Plumey). One drum is used, onto which the milk is fed by a smaller, unheated cylinder directly underneath it, which dips into the milk. The thickness of the film of milk on the main drum is regulated by adjusting the distance of the small cylinder from the drum. The heated drum is maintained at about 195° F. Concentrated milk is required in this process.

Gothman Process. A spirally corrugated, conical, heated drum is used, which works against a similarly corrugated surface in close contact with the corrugations of the cone. The heated drum has a temperature of between 212 and 217° F, and the milk is fed in at the wide end of the conical drum and is gradually worked to the thin end, from which the dried milk is brushed off.

Stauf Process. This is a spray-drying method and was the first successful application of a process proposed by Percy in 1872. The milk is sprayed in the lower part of a vertical chamber, through the bottom of which enters a current of warm air. The milk spray is carried upward by the warm air to the top of the chamber; the

[12] Davies, W. L., "The Chemistry of Milk," Chapman and Hall Ltd., London, 1936.

semi-dried powder is then made to pass to adjacent compartments where evaporation of moisture is completed.

Percy Process. This was invented in 1872 by Samuel Percy. It covered a method of atomizing fluids and drying fluids by the use of heated or cooled air or gas. This cooled air or gas broke up the substance into particles which were blown into a heated chamber and thereby dried.

McLachlan Process. This is a modification of the Stauf process. The spray of milk enters the top of the drying chamber and drops through an atmosphere of heated air. In dropping through the air, the particles give up their moisture and fall to the bottom of the chamber as a dry powder.

Bevenot-DeNeveau Process. Atomized milk is sprayed into chambers provided with air vanes through which hot (212° F) air passes.

Merrell-Gore Process. This involves the use of concentrated milk, which is forced under pressure through a spray nozzle into a chamber. The spray nozzle is located nearer the top of the chamber than the bottom. The atomized milk meets a violent current of hot air projected into the chamber near the spray nozzle. The dried milk falls to the floor of the drying chamber; the lighter particles, which may be carried away through the exhaust duct, are retained on cloth filters.

Krause Process.[13] This process, which has been, and may still be, widely used in Europe, atomizes the milk by feeding it into the center of a rapidly revolving disk (5000 to 24,000 rpm) driven by a steam turbine. The disk is placed in the center of the drying tower, which is from 6 to 15 ft in diameter. The atomized material meets a blast of hot air which dries the milk in a fraction of a second. Most of the powder falls to the bottom of the tower where it is swept out through openings in the floor by means of a rake or scraper. Fine powder carried out through the exhaust duct is caught by a dust collector.

Buhl Process. Atomized milk is dried in superheated steam at such a temperature that when the steam is charged with the moisture of the milk it still remains above 212° F and is not saturated.

Rogers Process. The milk is sprayed in from the top of a dry-

[13] Das Krause Trocknungsverfahren, *Arbeiten aus dem gebiete der Lebensmitteluntersuchung.*

ing chamber and hot (180-200° F) air is admitted near the bottom. Concentrated milk is used.

Gray-Jensen Process.[14] This process is quite popular in the United States. It incorporates a number of improvements such as minimizing loss by entrainment, low moisture content of the product, preservation of reconstituting properties and maximum economy of operation. Of particular interest in the Gray-Jensen process is the preconcentration chamber before the spray chamber.

Dick Process. The milk is atomized by centrifugal force, and the drying chamber is made up of four zones by a suitable location of the intake and exhaust ducts.

Huillard Process. An endless metal belt, travelling about 260 ft per min, passes through the milk to be dried. The belt is inclosed in a tunnel with partitions forming diverting baffles crossed by a hot-air current which travels in a direction opposite to that of the belt. When the milk on the belt is dry, it crosses a "threshing box" which detaches it.

The spray processes most widely used today in the United States are the Krause, Gray-Jensen and Rogers.

Modern Drying of Milk

To obtain a good dry milk, it is necessary to start with a good fluid milk. Although the temperature used in drying milk destroys many of the microörganisms present in the raw product, dehydration cannot purify a dirty raw milk of high bacterial count. It is therefore necessary to start with a clean, raw milk of low bacterial population. Upon delivery at the drying plant, the milk should be subjected to rigid inspection.

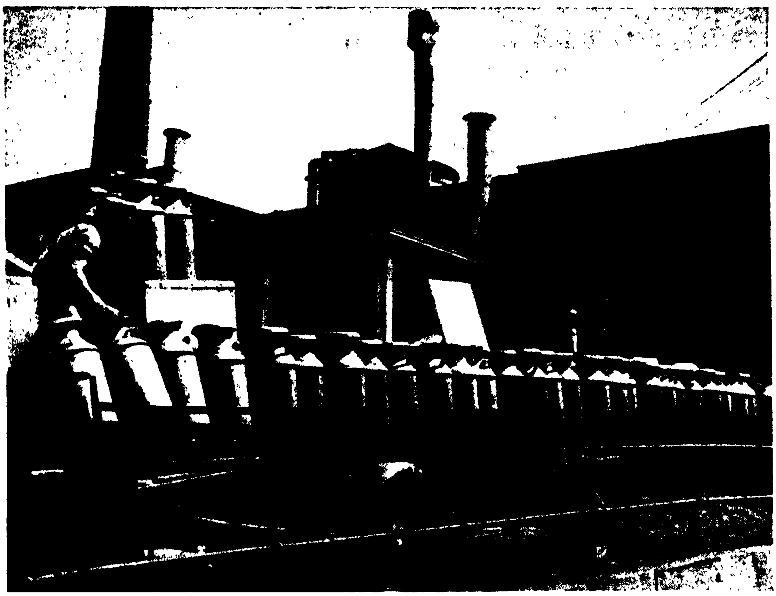
Odor and Taste. The inspector usually takes the cover from each can of milk delivered and smells the cover. This technique has been found to be more reliable than smelling the contents of the can. It requires an experienced man to carry out this test and to judge whether or not certain cans should be rejected.

Temperature. This is not measured by a thermometer because it would require too much time, although one may be used in case of dispute. The inspector merely places his hand on the can and notes whether it is warm; he also may obtain an indication by

[14] Gray, C. E., and Jensen, A., U. S. Pat. 1,078,848 (1913); Gray, C. E., U. S. Pat. 1,107,784 (1914).

the temperature of the air in the can when he removes the cover to note the odor of the contents.

Titratable Acidity. The value of this test has been the subject of much dispute and not all manufacturers consider it worthy of adoption. If the milk is titrated, it should not contain more than 0.18 per cent acid, calculated as lactic. Acidities much higher than this will cause the milk to coagulate during processing. However,



Courtesy U. S. Dept. of Agriculture. (Photograph by Forsythe)

FIG. 31. Fond du Lac County, Wis., farmers deliver milk at the rate of 150,000 pounds a day on the platform of the Galloway-West Company in Fond du Lac. Their empty cans boomerang back to them on the conveyor line.

authorities believe that high acidity alone should not form the basis for rejection of the milk, but that the results should be interpreted in the light of other factors. For instance, if the milk is warm upon delivery and also has a high acidity, it should probably not be used.

Alcohol Coagulation Test. Equal parts by volume of 75 per cent ethyl alcohol and milk are mixed. In the presence of certain substances a coagulum will form, and a positive test indicates possible trouble in subsequent processing. Like titratable acidity, it is

not recommended as the sole basis for rejection or acceptance of delivered milk.

Sediment Test. A pint of milk is filtered through a small circle of filter paper or absorbent cotton. The amount of dirt in the milk will be indicated by the color of the disk. Dirty milk will stain the disk brown or black; with clean milk the disk will be white or creamy.

Methylene Blue Test. This test is generally used to determine the quality of the raw milk because it does not require the skill of a bacteriologist and little equipment is needed. The test is based on the fact that when a small amount of methylene blue is added to milk it will be reduced to the colorless leuco base, the time of reduction being closely correlated with the number of bacteria in the milk. The test is performed by using tablets of methylene blue (methylene blue thiocyanate certified by the Committee on Standardization of Biological Stains). One tablet is dissolved in exactly 200 cc of sterile or freshly boiled water. Solution is complete when the tablet is allowed to stand in 200 cc of water over night. One cubic centimeter of this solution is added to 10 cc of the milk to be tested, in a test tube. The tube is stoppered and incubated at 37° C (98.6° F). At the end of the incubation period, the milk is classified according to the time required for the methylene blue to be reduced. The American Public Health Association has set up the following classification:

Class 1. Excellent, not discolored in 8 hrs.
Class 2. Good, discolored in less than 8 but not less than 6 hrs.
Class 3. Fair, discolored in less than 6, but not less than 2 hrs.
Class 4. Poor, discolored in 2 hrs.

The *resazurin test,* more rapid than the methylene blue test, may be used, but some authorities doubt its accuracy.

Besides low bacterial count, sweet milk for drying, as already pointed out, should be low in acidity. Early patents dealing with the dehydration of milk attempted to avoid the difficulties encountered when high acid milk was used, by adding sodium, potassium or calcium carbonates. Under present methods of food processing, such a practice is neither desirable nor necessary.

Concentration (Condensing). Practically all spray-dried milks are concentrated before drying because spray drying is an expensive way of removing water. If single-drum dryers are used, it is also necessary to concentrate because fluid milk has such a low viscosity that it is incapable of providing a satisfactory film thickness. When double drums are used, and the milk feed trough rests on top between the rolls, concentration is not necessary.

The milk is generally concentrated to about 4.0 to 4.5 to 1. If concentration is carried too far, lactose may crystallize from the milk as it is cooled, and there may also be trouble from plugging of the spray nozzles. Before being pumped to the concentrators, the milk is heated to near its boiling point (190-210° F). This treatment serves to de-gas the milk so that there will be less foaming in the pans, and it also serves as pre-sterilization. No doubt de-gassing could also be accomplished by means of efficient de-aeration equipment.

Concentration is carried out in vacuum concentrators of the rapid recirculation or recompression type. In the former, the heating element consists of milk-heating tubes surrounded by a steam chest. The milk level is part way up the tubes, and the steam circulating outside the tubes causes the milk to boil, partly vaporize and to travel with high velocity up through the tubes. The latter type involves the utilization of a part of the milk vapor generated in the concentrator. Temperature and pressure of the milk vapors are increased by injection of high-pressure steam and the compressed milk vapors thus obtained are reused as a heating medium. The pounds of water evaporated per sq ft per hour in these concentrators will vary from about 30 to 46 lbs depending upon the vacuum used and saturated steam pressure. For a discussion of the thermodynamics of the concentration of milk, the reader should consult Hunziker.[15]

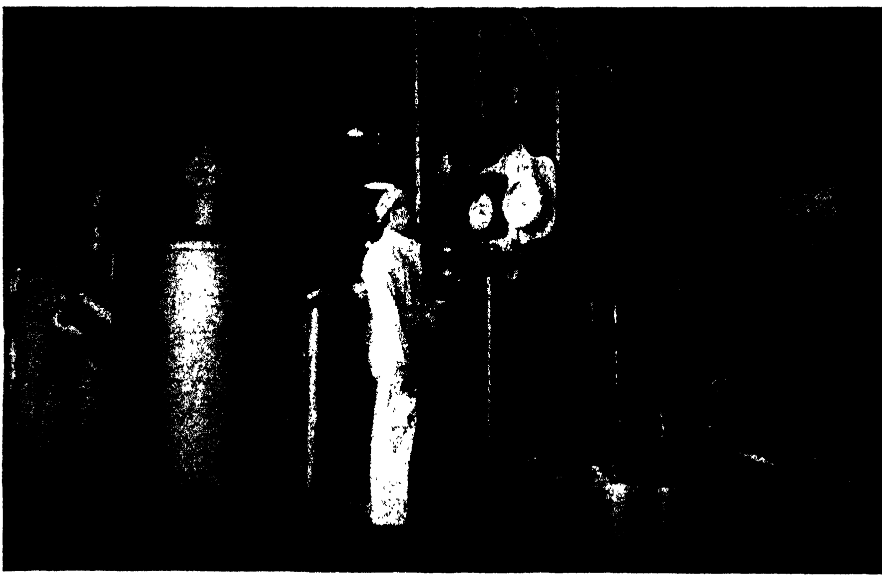
Concentration is generally carried out at temperatures of between 130-145° F, corresponding to a vacuum of 24 to 27 in of mercury.

Proper concentration is judged by taking a sample from the pan without breaking the vacuum. This is accomplished by two valves and a short nipple between them, at the lowest point of the pan.

[15] Hunziker, O. F., "Condensed Milk and Milk Powder," 5th Ed., p. 505, Published by the author, La Grange, Ill., 1935.

Concentration is generally not carried out more than 4.0 or 4.5 to 1 if pressure spray nozzles are to be used in spray-drying. If a Krause type atomizer is utilized, the milk can be concentrated more without danger of clogging the spraying equipment.

As already mentioned, concentration effects economy in drying. Hunziker,[15] quoting from Scott's data, shows that there is a saving of 38 per cent of the fuel required by concentrating milk to 40 per cent solids. In addition to the fuel saving, Hunziker points out that there is an increase in the capacity of a given dryer and a reduction in operating time.



Courtesy U. S. Dept. of Agriculture. (Photograph by Forsythe)

FIG. 32. Evaporation of milk prior to drying.

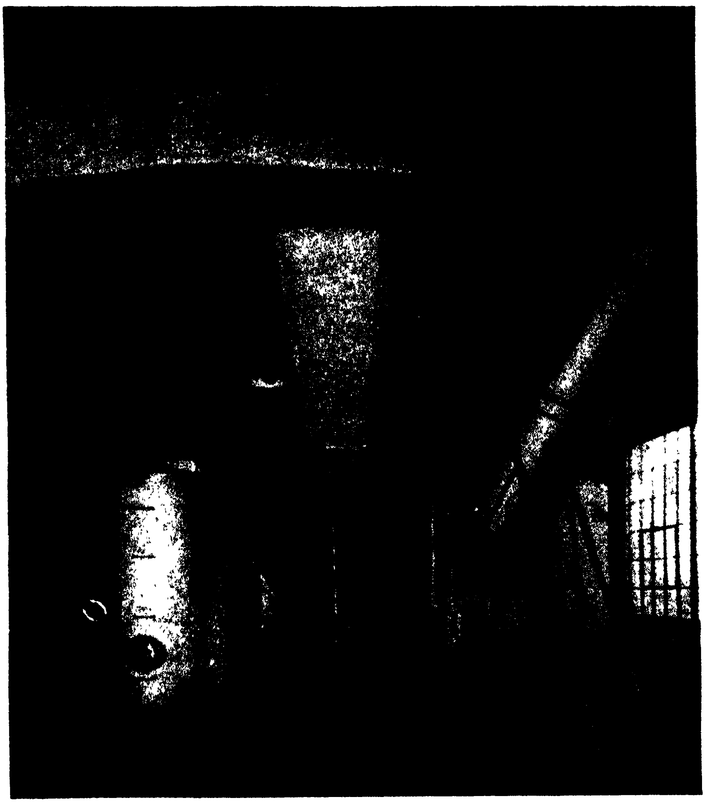
Concentration of the milk before drying yields a more compact dried product than is obtained from milk not concentrated before drying. Because dry milk obtained from concentrated milk is more compact, there is less entrainment loss than in the case of the fluffy product obtained from milk dried without concentrating.

Homogenizing. It is not necessary to homogenize concentrated milk if pressure spray nozzles of about 3000 lbs are used. It is, however, necessary to homogenize the milk if it has not been concentrated. If drum dryers are used, it is also considered desirable to

homogenize in order to prevent "churning" when the powder is reconstituted. Homogenizing is carried out at 2500 to 3000 lbs pressure at 140° F.

Some Engineering Aspects of Spray-drying of Milk

Before the milk is sprayed into the drying chamber, it is generally reheated to 140 to 160° F, because it is believed that this treatment causes a more rapid and complete drying of the sprayed milk.



Courtesy Mojonnier Bros. Co.

FIG. 33. Spray dryer.

Temperature of Air Used for Drying. As in the case of cabinet and tunnel dryers, for solid materials, the temperature of the air used in spray-drying milk should be as high as the product will stand without injury. Spray-drying, carried out in such a manner that the hot air entering the chamber mixes with the milk spray

in a turbulent manner, will permit higher air temperatures than in those cases where turbulence is not present. This is due to the fact that in the former instance there is a more rapid evaporation of water and hence more cooling. Generally, the air entering the spray chamber has a temperature of 265° F, but in some instances it may be as high as 390° F. If turbulent mixing is not obtainable, air temperatures of 160 to 200° F are used.

The air should be drawn through a filter located at the intake of the heating unit. This filter may be a water spray or wire-mesh gauzes over which water is trickling and through which air is sucked.

Air Velocity. If the air velocity is too great, entrainment losses and friction in the ducts will be increased, which will necessitate more power. In general, the velocity of the air in the intake and exhaust ducts should not exceed 600 linear ft per min, and in the heating chamber and dryer not more than 1200.

Blower Location. In most cases, the blower is installed at the intake of the cold air to the heating unit. In some instances it is installed in the exit of the drying chamber. This latter location has the advantage of creating a slight vacuum in the drying chamber which theoretically should increase the rate of evaporation.

Temperature of Discharge Air. The air leaving the drying chamber generally has a temperature of from 120 to 200° F, depending upon the temperature of the intake air.

Methods of Heating the Air. The majority of milk-drying plants heat the air by means of steam coils equipped with control valves. Exhaust steam is quite often used in the first coil sections, and high-pressure steam in the subsequent sections. Indirect methods of heating may also be used. In heating by means of furnaces, the air is conducted through flues installed in a furnace. The method has the disadvantages of difficult temperature control and rapid deterioration of the heating tubes. There is also danger of contamination from scale and rust breaking loose from the flues. Heating by flue gas is economical, provided there is a plentiful supply of gases at sufficiently high temperatures.

Removal of Milk from the Drying Chamber. It is necessary to remove the dry product as quickly as possible from the drying chamber. Prolonged exposure to the heat of the chamber is deleterious to both flavor and keeping quality of the milk. The milk is there-

fore continuously removed from the dryer by suction fans installed at the bottom of cone-shaped dryers, or by a system of brushes and a screw conveyor.

Dust Collectors. Some of the dry milk particles will be of such an extreme degree of fineness that they will not drop to the bottom of the drying chamber and will be carried along by the exhaust air. These particles are trapped in dust collectors, the most common type being a series of filter bags 6 to 10 ft high and 8 to 10 in wide, provided with mechanical shakers to prevent clogging. In some instances

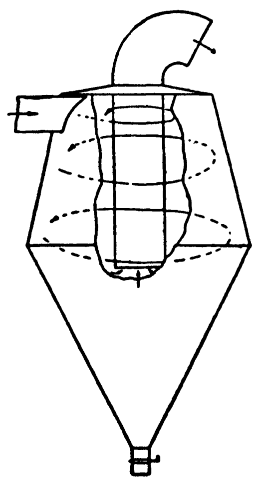


FIG. 34.

A dust collector.

From "Industrial Chemistry," 2nd ed., by E. R. Riegel, New York, Reinhold Publishing Corp.

these filter bags are supplemented by a preliminary recovery system consisting of a series of large cloth screens suspended in a chamber through which the air passes before it reaches the filter bags. Or the air from the drying chamber may first go through a cyclone which is a cylindrical container with baffles and a cone-shaped bottom. The air impinges on the walls and baffles of the cylinder, releasing a portion of the milk particles.

Losses will amount to from 6 to 8 per cent in the case of milk that has not been concentrated before drying, and about 2 per cent in the case of drying concentrated milk.

Changes Taking Place in the Drying of Milk

Albumen. At the usual temperatures in drum-drying, there is coagulation of the albumen and globulin, although this has been disputed by some authorities. In spray-drying, because of the low

temperatures to which the liquid product is heated, the albumen and globulin are believed to be unaltered and are found in the reconstituted milk in the same form in which they existed originally.

Casein. It is probable that casein does not undergo any chemical modification during drum-drying of milk provided the milk used is not of high acidity; but it probably does suffer an alteration of its colloidal structure. This is one reason why drum-dried milks are less soluble than spray-dried, for alteration of the casein has not been observed in the latter.

Lactose may caramelize in the drum-drying of milk, and this is especially true if a sheet of the milk sticks to the drums and becomes over-heated. Such dried milks, when mixed with uncaramelized milk, will cause yellow specks throughout the product. Most dried milks will have a yellow cast because the lactose, which is in the anhydrous form, becomes yellow in color at 150 to 160° F.

Salts. The action of concentration and heat causes slight modifications of the original mineral balance of the milk. In drum-drying, there may be changes in the phosphates, but in spray-drying there is no apparent alteration.

Acidity. Porcher [16] claims that drying causes a slight reduction in acidity, attributed to the escape of carbon dioxide. However, Porcher states that, generally speaking, the acidity of milk is not altered by drying provided no alkali is added before drying.

Enzymes. If, before and during drying, the milk was not heated above 65° F, enzyme destruction will be only partial. Porcher [16] states that catalase and reductase have never been found in freshly prepared dry milk, and that peroxidase is only partially destroyed. Enzyme destruction is greater in drum-dried than in spray-dried milk because of the higher temperatures used in processing the former.

Moisture Content of Dry Milk. It is important to keep the moisture content as low as economically possible. According to Davies,[17] the moisture content of spray-dried milk should not exceed 5 per cent, and that of drum-dried 8 per cent.

Yields. One hundred pounds of fresh

[16] Porcher, C., "Dry Milk," Olsen Publishing Co., Milwaukee, Wis., 1929.

[17] Davies, W. L., "The Chemistry of Milk," p. 427, Chapman & Hall, Ltd., London, 1936.

skim milk will yield 9 pounds of dry skim milk.
whole milk will yield 12.5 pounds of dry whole milk.
buttermilk will yield 9 pounds of dry buttermilk.
fluid cream * will yield 28 pounds of dry cream.

Dry whole milk, according to Federal Standards, should contain "not less than 26 per cent milk fat and not more than 5 per cent of moisture."

Table 35. Composition of Dry Milk.
(*From Rogers and others*)

Constituent	Dry whole milk	Dry skim milk	Dry soluble whey protein powder	Dry cream
Water (%)	1.4– 6.4	1.0– 7.4	3.28–11.21	0.56– 0.8
Protein (%)	24.6–32.1	33.3–37.7	28.02–12.62	11.12–19.1
Fat (%)	25.0–29.2	1.0– 2.6		50.40–71.1
Lactose (%)	31.4–37.9	45.6–52.2	43.02–68.52	14.74–25.4
Ash (%)	5.6– 6.2	7.9– 8.2	46.5 – 7.65	2.43– 4.1

Dry Buttermilk

Buttermilk may be dried with or without previous concentration. If not concentrated, it is usually dried by the Collis method [18] which consists of a single-drum unit. The milk is delivered to the drum by a spray pipe through which it is pumped from a supply pan underneath the drum. The spray pipe is located so that the milk is applied tangentially against the under side of the drum and in the same direction as the drum is revolving. The delivered milk has a temperature of about 150-160° F and is maintained at this temperature by excess milk spilling back into the supply pan beneath. Drying temperature is approximately 200° F, and as the milk comes from the drum, it contains from 10 to 15 per cent moisture.

If the Collis method is not used, it has been found advantageous to concentrate the milk before drying. Concentration increases the capacity of the drying unit, and stabilizes the milk emulsion. Double-drum units are used for drying concentrated buttermilk.

Dry Whey

Whey is the liquid residue produced in the manufacture of cheese. In Switzerland, some of the cheese factories concentrate sweet whey to yield crude lactose. The mother liquor obtained from crystallizing the crude lactose is dried by either drum or spray dryers. Acid

* 20 per cent butterfat.
[18] Collis, N. P., U. S. Pat. 1,317,777 (1919); U. S. Pat. 1,356,340 (1920).

whey, obtained from acid-drained curd, has been used for feeding hogs. Since whey contains only about 4 per cent solids, the cost of drying, apart from that of installing drying equipment, makes dry whey a rather high-priced commodity. Whey may be dried on drums, but because of the high temperatures used, there is a certain amount of caramelization of lactose. Attempts have been made to prevent this by using a concentrated whey, partially neutralizing, or by mixing the whey with milk.

If whey is drum-dried, the product comes from the drums as a gummy solid, and upon cooling crystallizes to a hard cake. The cake is ground, yielding a creamy powder with a "sandy" taste due to lactose. The material is quite hygroscopic and must therefore be stored in moisture-proof, moisture-vapor proof containers.

The moisture content of the finished material is between 8 and 12 per cent.

Dry whey may be used in bread making and in the preparation of certain types of soups.

Malted Milk

The process of making malted milk was invented by Horlick in 1883. It is obtained by mixing whole milk with a mash of barley malt and wheat flour, allowing the starch to hydrolyze to malt sugar and dextrin, and then drying. According to Federal standards, it must contain "not less than 7.5 per cent fat, and not more than 3.5 per cent moisture."

The manufacture of malted milk may be divided into four phases:

1. Germination of the barley, and malting.
2. Separation of the spent mash.
3. Addition of whole milk.
4. Concentrating and drying.

Germination of the Barley, and Malting. Clean barley grain is first steeped in water at 68° F for 24 to 48 hours, or until the grain is thoroughly soaked. During steeping, the grain swells, and at the end of the steeping period contains from 45 to 50 per cent moisture. The steeped grain is then allowed to germinate, and this is accomplished by three methods: by spreading on concrete or tile floors to a depth of from one to two feet; by placing in long bins with

perforated bottoms, or by loading into revolving drums supplied with a flow of warm, moist air. Moisture and temperature must be carefully controlled because these two factors determine the development of the enzyme, diastase. Germination requires from 5 to 7 days at a temperature of 70 to 75° F. After germination has been completed, the sprouted barley is transferred to a kiln similar in construction to those sometimes used for drying apples (p. 40). Initial drying temperatures are from 80 to 110° F; this temperature is maintained for one to two days, after which it is increased to

Table 36. Composition of the Barley Kernel and Barley Malt.
(*Hunziker.*)

Constituent	Moisture (%)	Protein (%)	Fat (%)	Sugar (%)	Starch (%)	Fiber (%)	Ash (%)
Barley kernel	15	10	2	11	55	5	2
Barley malt	2	11	0	16	63	6	2

120° F until the barley malt is dry. Properly dried barley malt should not contain more than 3 per cent moisture. The finished product is tested for its diastatic activity, and should have a diastatic value of between 130 and 140° Linter.*

The barley malt is now ready to be mashed. This is carried out by mixing wheat flour with the malt in the proportion of about 10 per cent malt and 90 per cent wheat flour, although this proportion will vary widely with different manufacturers. If the mash contains a relatively large amount of barley malt in proportion to wheat flour, the product is generally sold as "double malted."

Since the starch in the wheat flour is in an insoluble state and cannot be readily acted upon by the diastase in the malt, it is necessary to treat the flour in boiling water. The starch cells swell and burst, forming a pasty mass which is subsequently cooled before mixing with the malt.

The malt is crushed by running between rollers and is then mixed with the flour paste. The mixture is heated for 30 min at 113° F, and then the temperature raised to 158° F at the rate of 1° C a minute until 70° C has been reached. This temperature is maintained for one hour and mashing is generally completed in from 2 to 3 hours, or when all the starch has been converted to maltose and dextrin.

* This means that 100 lbs of dry malt will invert 1300 to 1400 lbs of soluble starch.

Separation of the Spent Mash. The mash is allowed to stand until the barley husks, which give the finished product its malt flavor, have settled. The extract is then drawn off, and may or may not be filtered according to the nature of the product desired by the manufacturer. In some instances sodium bicarbonate is added to the extract to partial neutrality, and sometimes sodium citrate or disodium phosphate is used as emulsifier.

Addition of Whole Milk. The filtered or unfiltered extract is mixed with whole milk in such proportions that one pound of the dried product contains an amount of milk solids equivalent to 2.2 pounds of fluid whole milk. In general, this means that the mixture contains from 40 to 45 per cent whole milk and 55 to 60 per cent extract. The mixture is held at 40 to 50° C (104°-122° F) for from two to four hours to promote full enzyme activity of the malt extract.

Concentrating and Drying. Concentrating and drying may be carried out either in vacuum pans provided with a mechanical agitator, or by a vacuum drum dryer. It is necessary to dry at low temperatures to prevent destruction of enzyme activity. The temperature should therefore not exceed 130 to 140° F.

Table 37 gives the composition of malted milk. The product is used for beverages, desserts and ice-cream drinks. Although carefully prepared malted milks have starch digestive properties, they are not of significance in aiding the normal process of starch digestion in the human organism.

Table 37. Composition of Malted Milk
(*Hunziker 15, p.*[147])

Product	Moisture (%)	Fat (%)	Ash (%)	Crude protein (%)	Casein (%)	Lactose (%)	Maltose (%)
Horlick's (1923)	2.15	8.10	3.96	14.80	6.44	10.04	43.40
Borden's (1923)	2.00	8.95	2.77	14.11	7.40	11.81	47.60
Thompson's (1925)	2.15	8.10	3.85	12.15			72.95
Coor's (1923)	2.06	8.97	3.84	14.91	9.25	15.71	38.40

Dehydrated Butter

Dehydrated butter is not dried in the strict sense of the term, but is butterfat which is more stable than butter. Considerable work on this product has been done in New Zealand, where it is produced on a commercial scale. The process is briefly as follows: Pure, unsalted whey butter is melted in a steam-jacketed kettle and

the melted fat and water run into a cylinder where the water is allowed to settle from the fat. The fat is drawn off and passed through a centrifuge to break any oil-water emulsion present. The centrifuged fat still contains some water, which is removed by vacuum drying. The dried fat thus obtained is sealed in tin cans and does not require refrigeration to prevent spoilage. The material may be used without any further manipulation, but is brittle, does not readily spread and has a tallowy taste. It is preferable to reconstitute into butter by adding water, dry milk and salt.

Table 38. Approximate Weights Per Cubic Foot of Eggs and Milk.

Commodity	Wt. per Cu Ft (lbs)
Fluid whole milk	64.6
Dry whole milk	32.1
Fluid skim milk	64.7
Dry skim milk	41.3
Dry whole egg	31.8
Shell eggs (one case of 30 doz)*	22.5

*It has been assumed that one case of 30 doz eggs will measure 1′ × 2′ × 1′ or 2 cu ft and will weigh 45 lbs.

Suggested Readings

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Chapter 5

Dehydration of Meat, Fish and Beef Blood

Although salting and drying meat is an old procedure, and unsalted dried meat is known today in the commerce of certain South American countries, its production in the United States has just started; it has been stimulated by the need of animal protein in countries of the United Nations. It should be pointed out, however, that the dehydration of meat in the United States may be considered to be still in the experimental stage.

Preparation of Meat

Beef. In general, the cheaper cuts are used for dehydration, the cattle coming from that class of beef known as "canners." Such cattle are not satisfactory for the fresh beef market and are used primarily for canned products.

The beef is taken from the "freezer," boned in the usual manner and the fat carefully cut away. It is important to have not more than 10 per cent fat in the meat to be dehydrated. Excess fat will delay drying by encasement of the lean meat.

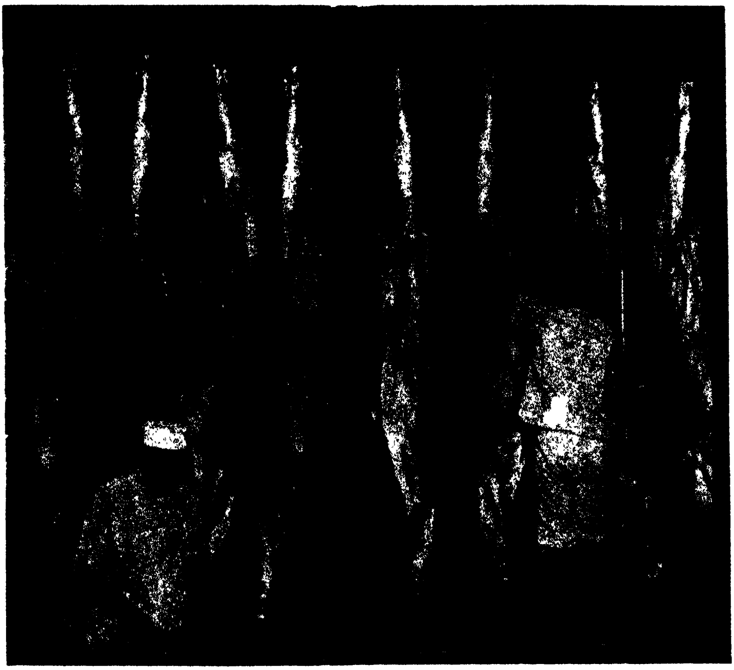
A good boner can bone and trim about 500 pounds of beef forequarter or 750 pounds of hindquarter in an 8-hour day.

After trimming and boning, the meat is ground in a power-driven grinder; it may be ground after cooking rather than before. Some dehydrators cut the material in a rotary meat cutter. The sizes of the cut pieces vary from about ¼ to 2 in, depending upon the subsequent treatment of the meat.

Precooking. The purpose of precooking is to kill all non-spore-forming pathogenic microörganisms, and to inactivate enzymes. Precooking also removes part of the water and coagulates some of the proteins in the meat juices. Uncooked meat requires a longer drying period, and the dehydrated product will not reconstitute as readily as dehydrated precooked meat. The reason for this is that cooking alters the collodial structure of the meat proteins and thus causes

more rapid diffusion of moisture to the surface of the material being dried.

There are two methods of precooking: in steam-jacketed kettles, and upon steam-heated drums. In the first method, the cut meat is placed in a kettle provided with a vertical revolving paddle, and heated at atmospheric pressure for 30 min at 165° F. The meat may also be heated under pressure (about 1 lb gauge for 45 min), in



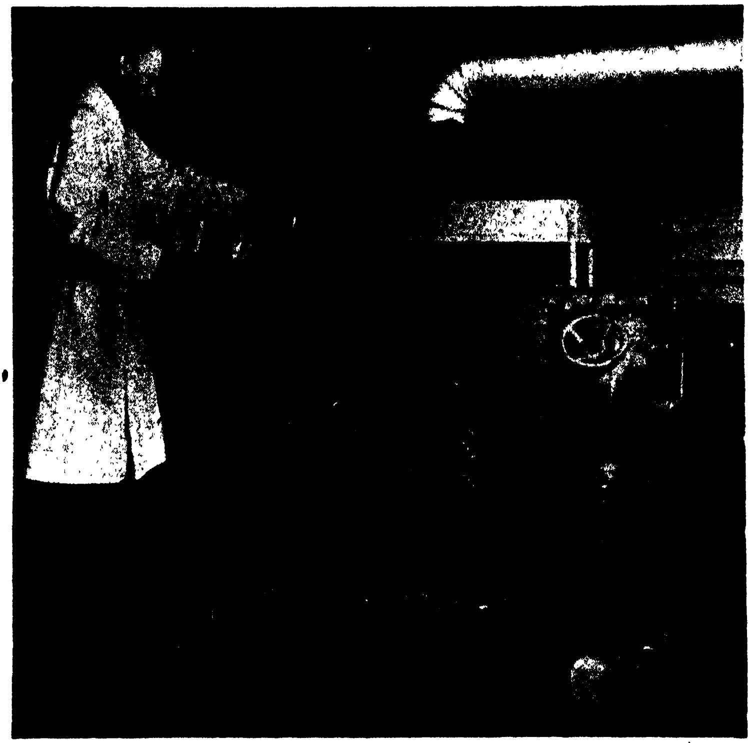
Courtesy U. S. Dept. of Agriculture

FIG. 35. Final inspection of beef in an Oklahoma plant.

which case sufficient water is added to prevent the meat from sticking to the kettle. Bacteriological tests have shown that heating to 165° F for 30 min is sufficient to destroy staphylococci and other food-poisoning organisms, if present. If precooked on steam-heated drums, the ground material is dropped between the rotating drums (set about 0.1 in apart) where heat and pressure remove from 20 to 30 per cent of the moisture. The meat sticks to the drum and is removed by a "doctor blade" or scraper. Drum dryers are of use in the preliminary stage of dehydration and may be used in place of a steam-jacketed kettle, but are believed not satisfactory for the entire process of drying, according to our present knowledge.

Drying. The precooked pieces, obtained by treatment either in a kettle or on a drum dryer, may be dried in a Roto-louvre dryer (p. 18), or in a cabinet.

In a Roto-louvre dryer, air at approximately 300° F and at a velocity of about 800 linear ft per min is forced through the meat.



Courtesy U. S. Dept. of Agriculture.

FIG. 36. Experimental drum dryer for precooking of meat prior to dehydration.

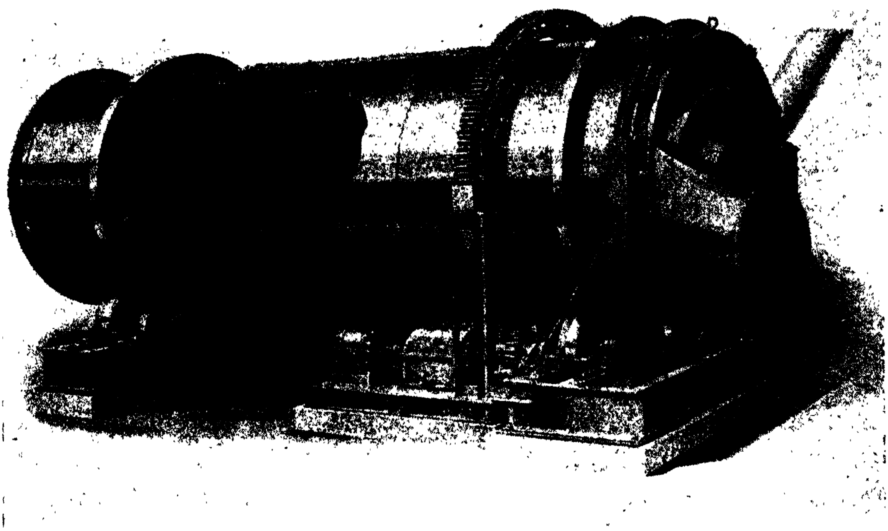
The discharge air has a temperature of about 150° F. It requires about 2 hours of drying in this type of dryer, and upon discharge, the meat has about 10 per cent moisture. A Roto-louvre dryer about 8 ft in diameter and 24 ft long will have a capacity of about 1000 lbs of dried (10 per cent moisture) meat per hour.[1] This type of dryer has certain objectionable features: it is difficult to keep clean; the incoming air temperature is rather high, and the dried product con-

[1] Stateler, E. S., "Swift Puts Meat Dehydration on a Production Basis," *Food Ind.*, 14, No. 10, 47 (1942).

tains large amounts of powdered meat. As knowledge of dehydration increases these objections will probably be surmounted.

If cabinet or tunnel dryers are used, the ground meat is trayed at the rate of about 1½ lbs per sq ft of drying area. Drying temperatures are about 160° F dry bulb and 120° F wet bulb.

Vacuum steam-jacketed melters used for rendering lard have been found satisfactory for dehydrating meat. Nearly every meat-



Courtesy Link-Belt Company

FIG. 37. Cutaway view of Roto-Louvre dryer.

packing plant has such equipment, and it is thus unnecessary for such plants to purchase special drying apparatus. The meat, cut into small pieces, is precooked in the melter. A vacuum is then applied and the drying completed.

Drying of Pork. Most of the meat now being dried commercially in this country is pork. Beef has been dried to a smaller extent chiefly because of the limited supply of the fresh commodity. Due to the quantity of fat in fresh pork, as well as the physical structure of the meat, pork cannot be so readily trimmed as beef. Attempts have been made to remove the fat during precooking, and the material is therefore cooked from 1½ to 2 hrs instead of 30 min, as in

the case of beef. Thorough precooking appears desirable not only from the standpoint of fat removal, but also for the destruction of *Trichinella spiralis*, if present.* This treatment produces a mixture of meat, liquor and fat. The meat is pressed in a hydraulic press, giving a press liquor of juice and fat. The press liquor is allowed to cool and the fat then skimmed off, or centrifuged, while the liquor is still hot. The residual liquor is concentrated *in vacuo* to the consistency of a thick gravy which is added to the meat as described below. The pressed meat is ground and dried in either a rotary dryer or in a cabinet until the moisture content of the product is about 5 per cent. The meat is then mixed with the concentrated liquor described above, until the moisture content of the material has been increased to 10 per cent. Part of the fat may also be returned, but the fat content of the finished product should not exceed 40 per cent.

To stabilize the fat in dried pork, small quantities of gum guaiac are sometimes added with some degree of success.[1]

Yield: A 165-170 lb hog carcass will yield from 17 to 18 lbs of dried product; a 500-lb beef carcass will yield from 65 to 70 lbs of dried meat.

Moisture content of the finished product should not exceed 10 per cent. In addition, fat should not exceed 30 per cent in the case of dehydrated beef, and 40 per cent, in the case of dehydrated pork. Specifications for dehydrated beef, according to Form FSC 1719 Agricultural Marketing Administration of the U. S. Department of Agriculture, are as follows:

"*Specifications:* Dehydrated beef shall consist of beef derived from the entire carcasses of boned cattle of U. S. canner grade or better. Meat from bulls shall be excluded. Closely trimmed beef cheek meat and beef head may be included up to 3 per cent of the total meat used. The meat shall be reasonably free from blood clots, bruises, stringy fibrous tissue, tendons, and sections of large blood vessels.

"Fat content of the finished product shall not exceed 30 per cent.

"Salt may be added to the meat to the extent that the finished product shall average not more than 3½ per cent sodium chloride.

"The meat shall be precooked a minimum of 30 minutes at not less than 165° F internal temperature.

"After precooking, promptly dry the meat until the moisture content of the dehydrated meat product does not exceed 10 per cent in any particle when placed into the container.

* The ingestion of the parasite *Trichinella spiralis* causes trinchiniasis (trichinasis) with a mortality in the United States of about 5 per cent.

"The dehydrated beef shall be packed as tightly as possible into rectangular or round tin cans, hermetically sealed with or without vacuum, and shall be packed into containers meeting the requirements of Federal Specifications for canned meat for export."

Cured Smoked Turkeys

Turkeys preserved in this manner are not dehydrated in the true sense of the term, but are only partially dried. The product has a smoky taste resembling ham, but with the texture of turkey. The method of curing does not permit dehydration because this would concentrate the salts of the curing solution to the point where they would be objectionable to the taste.

Besley and Marsden[2] have carried out the curing and smoking of turkeys under experimental conditions. It is not recommended that the project be undertaken on a large scale, for it is not certain that the results obtained under experimental conditions can be duplicated with equal success in quantity production. Smoked turkeys are, however, produced on a semi-commercial scale.

In Besley and Marsden's method, well-fattened turkeys equal to U. S. Prime or Special grade are used. The birds are subjected to overnight fasting (with access to water) and then slaughtered and de-feathered in the usual manner. Special care should be taken not to break the skin in the process, and all birds with torn skin should be rejected. After the turkeys have been picked and eviscerated, they should be chilled to a temperature of 30 to 40° F. Before being placed in the curing solution, the head, neck and feet must be removed and the body cavity opened at both ends so that there is a passageway between the two ends. It is also advisable to remove the tendons from the legs to permit better penetration of the curing solution.

Curing. The curing pickle consists of:

24 lbs sodium chloride.
12 lbs brown sugar.
8 oz sodium nitrate.
dissolved in 18 gals of water.

A 50-gal barrel will hold about 100 lbs of moderately large birds, if carefully packed, and will require the above amount of

[2] Besley, A. K., and Marsden, S. J., "Suggestions for Curing and Smoking Turkeys," *U. S. Dept. Agr., Bur. Animal Ind.*, A.H.D. No. 28 (Revised), 1941.

pickle. It will be necessary to weigh down the turkeys so that they will not float when the curing solution is added. The birds should be completely covered by the curing liquor, and the temperature of both the pickle and the turkeys should be approximately 38° F when curing starts.

It will require a curing period of approximately 1¼ days per pound for birds weighing from 14 to 20 lbs. During curing, the pickle will stratify, and it is therefore necessary to insure thorough mixing of the solution. This may be done by repacking the birds once a week, as suggested by Besley and Marsden, but it would probably be less trouble to provide the barrel with a bottom spigot, draw off the pickle and repour over the birds, repeating the operation several times. Or if the barrels are headed, they may be rolled.

Smoking. The cured turkeys are washed in warm water to remove surface curing liquor, hung until partially dry, after which they are ready for smoking.

In the smokehouse, the turkeys should be hung by either their wings or legs in such a manner as to provide for maximum exposure of the skins and for further drainage of the pickle. Smoke is provided by burning hardwood, and the finished product should have a brown color. This will require several hours. However, some desire longer smoking: 8 to 10 hrs each day for 3 to 4 days. Smokehouse temperatures should be between 135° and 140° F for most favorable results. Long smoking is not desirable because of danger of dehydration and possible concentration of the salt in the meat to such an extent that the taste becomes objectionable.

Highlands and Burns[3] suggest the following formula for a pickle:

Water	5 gals
Sodium Chloride	4 lbs
Sugar	30 oz
Oil of celery	8 cc
" " black pepper	8 cc
" " sage	5 cc
" " thyme	5 cc
" " marjoram	5 cc
" " bay leaves	6 cc
" " sweet basil	6 cc
" " coriander	5 cc
" " cardamon	5 cc

[3] Highlands, M. E., and Burns, J. W., *Food Ind.*, 13, No. 7, 46 (1941).

The oils are dissolved in 200 cc of ethyl alcohol with the addition of about one gram of gum tragacanth. Even under normal world conditions, this pickle would be considerably more expensive than that suggested by Besley and Marsden. However, Highlands and Burns believe that sodium nitrate is undesirable in the curing solution because it causes a reddening of the dark meat and gives the white meat a pink tinge.

Highlands and Burns cure the birds in the above solution for about 1.5 days per pound of dressed weight, and a 6- to 9-day smoking period at 110 to 115° F is recommended.

Drying, Salting and Smoking of Fish

Dried salt fish as a commercial venture in the United States dates back to the Massachusetts Bay Colony and the Puritans. The dry salting of fish was the first export industry of the country later

Courtesy: Fishing Gazette

Fig. 38. Drying fish on flakes at Gloucester, Mass.

to become the United States. Salt fish is still produced in Massachusetts, Newfoundland, and on the Gaspé peninsula, but the industry is on the decline.

Dehydration of fish (with the exception of shrimp), without

salting or smoking, still is experimental and commercial production awaits the results of laboratory and pilot plant researches. In this method of drying, the gutted fish is flaked, *i.e.*, split so it will lie flat, placed skin side down on screen or slatted trays and dried in cabinet dryers. The most favorable temperature and humidity conditions are as yet unknown. It is extremely difficult to dehydrate fatty fish because of the dripping of oil.

In the salting of fish, cod is the most often used, although in the southern states mullet and Spanish mackerel are utilized. The fish are usually split along the back just above the backbone and sometimes are so prepared that the two sides may be opened up like a book, the backbone acting as a hinge. The head may or may not be removed. The prepared fish are washed in clean water (clean sea water may be used) and then soaked for 30 to 60 minutes in dilute (4.5 per cent) brine. This treatment softens and removes traces of blood and "cuts" the slime.* After this preliminary treatment, the fish are again washed.

The technique of salting consists of packing the fish in hogshead with salt, about 8 bushels of salt being required per hogshead. This packing is carried out in a manner similar to "putting down" cabbage for kraut manufacture. Sometimes borax and sodium benzoate, in small amounts, are added along with the salt, but the use of these two chemicals is neither desirable nor necessary if salting is properly carried out. The salt removes water from the fish by osmosis, and probably the proteins are coagulated also. When the concentration of salt within the fish is the same as that of the brine in which the fish are immersed, the salter says they have been "thoroughly struck." This condition requires from 36 to 48 hours, depending upon the fish being salted. If salting has been too light, the fish will sour; if too heavy, the exterior will be leathery, while the interior will remain soft and flabby. This latter condition is known as "salt burn." It is important to use a good grade of salt. Tressler[4] states that the presence of calcium and magnesium sulfates will retard penetration of the salt and also cause blackening.

* Upon arrival from the fishing banks, the fish are covered with a slime which is believed to act as a sort of a protective coating against bacteria. The slime persists for 4 to 5 days and the fish buyer uses its presence as an indication of the freshness of the fish. Inasmuch as live fish are normally covered with slime which is constantly sloughing or washing off, this test has little scientific basis.

[4] Tressler, D. K., *U. S. Dept. Comm., Bur. Fisheries Doc.* 884 (1920).

After the fish have been "struck," they are removed from the brine and placed on flakes (slatted frames constructed of laths) located in a breezy, shaded place. Here they are allowed to dry; this requires from 4 to 5 days or longer, depending upon the weather. If it rains, or a fog rolls in, the flakes are covered with a tarpaulin. The fish are considered sufficiently dry when they contain about 12 per cent water (in the case of cod) and when the surface appears dry and hard. If the thumb is pressed into the thick part of the flesh, no impression should be left. The dried fish, after sprinkling with salt, are sometimes cut into strips, and are then ready for packing.

Organisms of the genus *Serratia* sometimes develop on salted, dried fish, giving it a red color. It is believed that these organisms come from the sea water, and although they are not pathogenic, they render the product unsightly.

Smoked fish is prepared by exposing the fish, either fresh or slightly salted, to the action of smoke obtained from burning hardwood. The fish are first dressed by eviscerating, splitting and beheading, and then soaked in 80 per cent to saturated sodium chloride for 10 to 20 min. This soaking period will give from 2 to 3 per cent sodium chloride in the finished, smoked product. After the salting has been completed, the fish may be dried in about the same manner as dry fish described above, with the exception that the fish are not permitted to become thoroughly dry. On the other hand, if they are too wet when smoked, they require too long a smoking period and will not color and dry properly.

Smoking is carried out in smoke houses, the style of which will vary according to the particular product being smoked. In general they consist of brick kilns with a cellar and first floor made of slats, and louvers in the gable of the roof. The fish are hooked on sticks and suspended on racks on the first floor of the smoke house. Fires of a mixture of chips and saw dust (oak or hickory) are made in the cellar of the kiln and the smoke rises by natural draft through the fish and out through the louvers, by means of which ventilation is controlled. For a satisfactory cure, the loss of water should amount to between 15 and 25 per cent of the weight of the fish; in commercial practice, the losses generally amount to from 10 to 20 per cent. After about 3 hours of smoking, the bottom layer of fish nearest the fire is dry enough to be removed.

The temperature during drying should not exceed 80-85° F, except during the beginning of the drying when the fish are still wet. If too high temperatures are used, there will be cooking and peeling of the skin. In order to develop the color and bring the oil to the surface, the temperature is generally raised during the last 30 min. of drying to 95-100° F.

In hot smoking, the temperatures used are generally from 150 to 200° F and the fish are partly or entirely cooked. This method is not used extensively in the United States, but in Germany and Sweden it is the most important procedure for smoking.

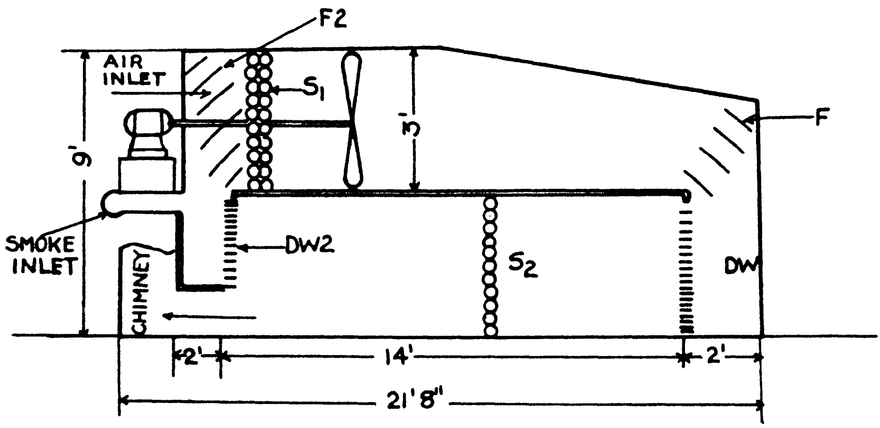


FIG. 39. Cabinet dryer for smoking and drying fish. After Cutting, *Chem. & Ind.*, 61, 365 (1942).

It will be noticed that in the methods described for smoking, there is no means of controlling humidity, and weather conditions will greatly affect the results. Cutting[5], working in England, has designed a combination dryer and smoke house in which temperature and humidity can be controlled. Referring to Fig. 39, the dryer consists of a cabinet about 22 ft long and 9 ft high. Circulation of air is obtained by a fan on top of the smoke chamber, the air passing along a tapering duct where it is deflected by fins (F) downward into the drying chamber and then through a diffuser wall (DW1). This wall gives a uniform flow of air in the drying chamber, the flow being regulated by horizontal slots in the wall, these slots extending the full width of the chamber. The slots are equally

[5] Cutting, C. L., "Engineering Problems of the Smoke-Curing of Fish," *Chem. & Ind.*, 61, 365 (1942).

spaced vertically and widest at the top so that the same volume of air is discharged from each slot. Air leaves the drying chamber through a second diffuser (DW2) where the widest slots are at the bottom. A second series of fins (F2) in the suction side of the fan deflects the exhaust air into the fan. Fresh air is also drawn through these fins at a rate controlled by shutters in the intake duct, and is heated by steam coils (S1), with an output of 70,000 Btu per hour, and thermostatically controlled. The heated fresh air is mixed with the recirculated air as it passes through the fan. Spent air and smoke are discharged through the chimney. There is also a secondary heater (S2) in the drying chamber, with an output of 90,000 Btu. Heating is supplemented, too, by smoke produced from the combustion of wood.

At an air velocity of 660 linear ft per min and with a dry bulb of 84° F and a wet bulb of 73° F at the inlet end, and a dry bulb of 79° F and a wet bulb of 72° F at the wet (exhaust) end, an overall loss of weight of 17 per cent was obtained in 4½ hours. The average heat input was about 20,000 Btu per hour.

Sun-Dried Shrimp

Practically all sun-dried shrimp are prepared in Louisiana. The shrimp are first boiled in dilute brine for about 15 min and then drained. The drained material is placed on drying platforms, which are built on posts so that air may circulate below and up through the shrimp on the platform. The shrimp are spread in layers 2 to

Table 39. Composition of Salted and Smoked Fish
(From U. S. Bur. Fisheries Bull. 1000)

Product	Water (%)	Total solids (%)	Fat (%)	Protein (N × 6.25) (%)	Ash (%)
Boneless salted cod	54.4	45.6	0.3	26.3	23.2*
Salt mackerel	43.9	56.1	25.1	18.6	2.6
Dried cod	11.6	88.4	4.9	72.0	5.2
Smoked halibut	49.4	50.6	15.0	20.8	2.1
Smoked herring	34.5	65.5	15.8	36.9	1.5

*Includes sodium chloride.

3 inches deep and it is necessary to turn them every few hours to obtain uniform drying. Under favorable weather conditions, drying is completed in about 3 or 4 days in summer and from 5 to 10 days in winter. The heads and shells are removed from the dried

product by means of rotating metal boxes provided with blowers; or laborers may tramp on them with shoes covered with clean sacks.

The product is packed into barrels holding 210 pounds.

From the data in Table 39 it will be seen that smoked fish are quite high in moisture and they will therefore not keep for more than a few weeks when stored at ordinary temperatures. Prevention of mold development is sometimes attempted by sprinkling the fish with a small quantity of fine, dry salt.

Dehydration of Beef Serum and Hemoglobin

The use of blood as a food in the diet of man is not new. Formerly regarded as a food only for savages, it is now a fairly important factor in the diet of civilized peoples. The use of blood in sausages has been known for some time, the practice being more common on the Continent than in the United States. During the First World War, serious attempts were made in Germany to utilize waste blood from slaughter-houses. The blood was dried and powdered and mixed with various spices and dried vegetables. One such product was Bovisan which was used chiefly as an addition to bread, zwieback, cocoa and chocolate. Other blood products born in Germany during this period were Prothämin, Sanol and Roborin. All of these seemed to have enjoyed rather a widespread distribution and considerable work was done on their nutritive value.

In the United States, little attention was given to blood as a possible human food until about 1920 when the high price of Chinese egg albumen suggested the possibility of using beef serum as a substitute for it. The pioneering work on this was carried out by Wescott and Atwood, and over a dozen patents were issued to these two workers covering the process [6] of obtaining dried beef serum. The old method of producing dried blood and serum consisted, in general, of catching the blood from cattle and letting it stand in a cool place until clotting took place. The clot was then cut into slabs and placed upon screens which retained the clot but allowed the exudate of serum to pass through. The serum was collected in suitable tanks, the first drippings being more or less colored with hemoglobin. The serum was dried in greased pans in a cabinet dryer at

[6] U. S. Patents 1,333,745 (1920); 1,348,194 (1920); 1,380,477 (1921); 1,452,863 (1923); 1,472,377 (1923); 1,472,378 (1923); 1,472,380 (1923); 1,495,364 (1924); 1,504,013 (1924); 1,513,953 (1924); 1,513,949 (1924).

temperatures below the coagulating point of the albumen. This method was unsatisfactory for a product to be used for food purposes, and all the material went into the technical field. Even here it was not entirely satisfactory because of its limited solubility.

Before describing modern methods, as evolved by Wescott and Atwood, for dehydrating blood for food purposes, it will be first necessary to outline briefly the biochemistry of blood.

Blood is composed chiefly of erythrocytes (red blood corpuscles), leukocytes (white blood corpuscles), and blood plates held in suspension in a fluid called plasma. These form-elements compose about 60 per cent of the blood by weight. Ordinarily, blood is a dark red opaque liquid, with a characteristic odor and saline taste. Blood can be rendered transparent by the addition of certain substances such as water; such blood is said to be laked. This is brought about by the liberation of hemoglobin from the stroma of the red blood corpuscles. The venous blood of man has a pH of about 7.35 (slightly alkaline), and buffer salts keep the pH nearly constant. Even in cases of the syndrome acidosis, the reaction of the blood is but slightly altered.

Among the most important constituents of blood plasma are the four protein bodies: fibrogen, serum globulin, nucleoprotein and serum albumen. When blood escapes from a blood vessel, it clots. This clotting is due chiefly to the interaction of enzymes, vitamin K, calcium salts, and fibrinogen. The normal phenomenon results in the precipitation of fibrinogen as long threads of fibrin which mingle with the red blood corpuscles to form the clot. Serum exudes from the clot; thus serum differs from plasma in that the former contains no fibrinogen or fibrin.

In the preparation of blood for food purposes, according to the method of Wescott and Atwood, only the blood from healthy animals is used. The animal is "knocked" and swung into the butchering position according to the usual technique. By means of a special knife, consisting of a common butcher knife mounted on an aluminum cup whose base is drawn out into a hollow cylinder comprising the handle, an incision is made in the neck near the jugular bifurcation, as in the regular butchering routine. The purpose of the special knife is to prevent the blood from coming in contact with the hide of the animal. In actual practice, however, it does not entirely fulfill this purpose.

The blood from each animal is caught in a separate container consisting of a five-gallon milk can that has been previously sterilized in live steam. Each can contains 240 cc (about 8 oz) of an anticoagulant, prepared by dissolving 20 lbs of sodium citrate and 4 lbs of sodium chloride in 20 gals of water. This solution is hypertonic*; the reason for this is to encourage crenation (shriveling) of the red blood corpuscles. The purpose of attempting to crenate the corpuscles will be explained later. In actual operation, only a few of the corpuscles are crenated, complete crenation being impracticable.

Each can, prepared as above, contains a number, and a tag bearing the same number is clipped to the animal's ear. When this animal has passed post mortem inspection by a Federal veterinarian, the tag is taken from the animal's ear and the can of blood released. If the animal fails to pass, the blood is dumped.

The amount of blood actually obtained from each animal varies, but averages about 22 lbs. In a light heifer, it will amount to about 11 lbs, while a good sized bull will yield as much as 31 lbs. More than these amounts could be obtained, but it is necessary to collect as quickly as possible so that the "kill" will not be retarded.

After the blood has been collected in the cans, it is passed through an 18-mesh screen to remove any clots. The blood cannot be pooled because this is likely to cause laking†, which will cause trouble later. The screened blood is passed through a centrifuge of the Sharples type provided with a special vane within the bowl, and designed to separate the whole blood into plasma and hemoglobin. Before the blood is passed through the centrifuge, a "cushion," consisting of 1 lb of salt in 5 gals of water is fed to the centrifuge. This prevents the corpuscles from rupturing by impact against the centrifuge bowl. Plasma from a previous batch may also be used in place of the salt solution.

Hemoglobin issues from one spout of the centrifuge, and plasma from the other. The red blood corpuscles are ruptured, probably in the head of the centrifuge bowl, and are carried from the centrifuge floating in plasma. It is important to have as little plasma as possible to float the erythrocytes, and the proportion is regulated

* *i.e.*, The concentration of salt in the solution is greater than the concentration of salt in the blood.

† The red blood corpuscles are destroyed.

by the degree of crenation of the corpuscles. If the water were efficiently extracted from the hemoglobin contained within the corpuscles, the latter would be floated out in this medium in place of plasma. This condition is never realized in commercial practice.

The plasma obtained is a light straw-colored liquid containing about 9 per cent solids. Its color varies according to the animal and the time of year. Cow plasma will have a yellowish tinge during the grass-fed season; heifer and steer plasma will run light in color, and bull plasma is slightly darker. If the blood has been laked before being centrifuged, or the concentration of sodium chloride in the anticoagulant has been too great, the plasma will be tinged with red. If the speed of the centrifuge is too slow, the plasma will also have a red tinge.

The hemoglobin coming from the centrifuge contains from 28 to 33 per cent solids, and is an extremely thick, viscous solution. After it has stood for a short time exposed to air, a thick crust will form. The material rapidly becomes putrid and must therefore be kept at freezing temperatures if it is not immediately dried.

Centrifugal separation, as described above, yields about 40 per cent hemoglobin and 60 per cent plasma, and these figures approach very closely the theoretical amount.

The plasma is pumped to stainless-steel or glass-lined jacketed tanks where it is defibrinated. This is carried out by raising the temperature of the plasma to 100° F and adding, while the mass is being stirred, a solution of calcium chloride in sufficient amounts to replace the citrate ions of the anticoagulant previously added. Roughly, this will amount to 1¼ lbs for every 100 gals of plasma. The plasma is slowly agitated and the fibrin soon separates as long gelatinous strings. The bottom of the tank is provided with a large dump valve beneath which is a screen to retain the fibrin while allowing the serum to drain through.

Fibrin is not dried, because it is insoluble, and is therefore shipped in a frozen condition to pharmaceutical houses. The material may be used for the preparation of proteose peptone (p. 177). Fibrin, prepared as described above, will have approximately the following composition:

Water	88.35%
Total Solids	11.65
Protein ($N \times 6.25$)	9.91

The filtrate from the fibrin is serum and still contains small amounts of fibrin which will "snow down" upon standing. The serum is therefore treated with carbon tetrachloride, added in quantities amounting to about 15 per cent by weight. The carbon tetrachloride and serum are carefully mixed so that an emulsion will not form. The carbon tetrachloride layer, consisting of fibrin and a slime of fats and lipoid bodies, is drawn off by gravity and the carbon tetrachloride recovered by distillation.

The serum obtained should be only slightly milky and lighter in color than the original plasma. It is concentrated in a circulating evaporator at temperatures below the coagulating point of the albumen. Evaporation is continued until the serum has a density of between 13 and 15° Bé, which corresponds to 25 to 28 per cent total solids. The concentrated serum is then spray-dried.

Spray-dried beef serum is a light yellow powder, with a faint "beefy" odor and saline taste. It has approximately the following composition:

Moisture	8.00%
Albumen ($N \times 6.37$)	73.26
Fat (ether extract)	0.15
Ash	17.2

The hemoglobin is dried without concentration, since it contains from 28 to 33 per cent solids as it comes from the centrifuge. Dried hemoglobin is a dark red powder, with a faint "beefy" odor and slight "animal" taste. It has approximately the following composition:

Moisture	7.50%
Protein ($N \times 6.25$)	90.41
Fat (ether extract)	0.45
Ash	2.11

One hundred pounds of whole beef blood will yield about 3.6 lbs of dried serum, 16 lbs of dried hemoglobin and 3.5 lbs of wet fibrin.

Dried hemoglobin, when dissolved in water, gives a brown solution and the characteristic absorption spectrum of methemoglobin, indicating that the hemoglobin has been oxidized during the process of dehydration. If a few drops of 3 per cent hydrogen peroxide are added to the hemoglobin solution and dehydration allowed to take

place in a vacuum, the dried product when dissolved again in water will give the absorption spectrum of hemoglobin.

Proteose Peptone From Fibrin

Fresh or frozen fibrin, obtained as already described, is washed as clean as possible. Properly washed fibrin is a tough, light yellow substance and entirely free from any jelly-like formations. To 100 lbs of the fibrin thus prepared is added 18 gals of approximately 0.6 per cent sulfuric acid and the material allowed to stand overnight at room temperature. This treatment plumps the fibrin so that it will be in a better condition for the subsequent peptic digest. While the fibrin is being plumped, a peptic extract is made by placing 10 lbs of fresh hog stomach linings in 3 gals of a 0.8 per cent solution of sulfuric acid and allowing to digest overnight at 35° C (95° F). The linings should be cut into small pieces, and the digest protected against putrefaction by spreading a thin film of toluene or xylene on the surface of the digest. The next morning, about 17 gals of an 0.8 per cent solution of sulfuric acid is added to the plumped fibrin along with the peptic digest, which should be a turbid liquid free from undigested matter and without a putrid odor. If it has such an odor, it should be discarded. The mixture is then digested at 50-60° C (122-140° F) for about 8 hours, or until solid lumps of fibrin are no longer apparent. When digestion is complete, the mixture is made slightly alkaline by the addition of ammonium hydroxide, boiled to prevent spoilage and to coagulate any undigested protein, and then filtered. The filtrate should be without turbidity and faintly alkaline to litmus. The clear liquid is evaporated *in vacuo* to a thick sirup and vacuum-dried at a temperature not exceeding 60° C (140° F).

The proteose peptone thus obtained should be completely soluble in water, giving a clear solution and a positive Biuret reaction. The peptone will have a pH of about 7.2, if the addition of ammonium hydroxide has been properly executed.

Yield. One hundred pounds of fibrin will yield about 16 pounds of proteose peptone.

Suggested Readings

Information Sheet on Methods of Meat Dehydration Used in the Department of Agriculture Experiments. *U. S. Dept. Agr., Agr. Res. Adm. Mimeo.* Oct. 15, 1942.

Stateler, E. S., "Swift Puts Meat Dehydration on a Production Basis," *Food Ind.*, **14**, No. 10, 47 (1942).

Besley, A. K., and Marsden, S. J., "Suggestions for Curing and Smoking Turkeys," *U. S. Dept. Agr., Bur. Animal Ind.*, A. H. D. No. 28 (Revised), 1941.

Tressler, D. K., "Marine Products of Commerce," Reinhold Publishing Corp., New York, 1923.

Kraybill, H. R., "Dehydration of Meat," *Ind. Eng. Chem.*, **35**, 46 (1943).

von Loesecke, H. W., "Outlines of Food Technology," Reinhold Publishing Corp., New York, 1942.

Chapter 6

Plant Sanitation

In general, the dehydration industry, particularly that pertaining to vegetable dehydration, has been greatly expanded during the past two years, but unfortunately in some instances little thought has been given to the sanitary aspects of the problem. Sanitation of dehydration plants should be on the same basis as that of canneries. Twenty-three years ago Prescott recognized that the dehydration of fruits and vegetables should be placed upon a more careful basis when he summed up the situation as follows[1]:

"After dehydration, fruits and vegetables should be packed at once in suitable tight receptacles or stored in bins which have been carefully prepared and which have adequate protection against vermin, insects, molds and other microbic enemies. Such storage receptacles or containers should prevent access of moisture in sufficient amounts to render the food material capable of fermentation or decomposition. The methods of handling the finished product in the factory should be such as to preclude infection of any sort. Care should be taken to impress upon the manufacturer that he is dealing with a food material and that it is essential to the welfare of the consuming public that such food materials should be placed before the consumer in a wholesome and uninfected condition."

In order to obtain these objectives, it is necessary to handle the product in a clean and sanitary manner and in a clean plant. The practice of running a plant twenty-four hours a day with only an occasional shut-down for a hasty cleaning cannot be considered as conducting processing in a sanitary manner. All equipment should be thoroughly flushed and steam-sterilized at the end of every 8-hour shift. High-pressure steam nozzles are available for adequate steaming.

Where trays are used for dehydration, it is necessary that these be kept clean. One method of accomplishing this is to subject the

[1] Prescott, S. C., "What Should be the Basis for Control of Dehydrated Foods," *Am. J. Public Health*, **10**, **324** (**1920**).

trays to streams of clean water while being brushed. Automatic machines may be devised for this, but such machines cannot be purchased on the market, and the dehydrator usually builds his own machine. After brushing and washing, the trays are cleaned with live steam. A 3-minute steaming period is usually sufficient, but care must be taken that every part of the tray is exposed to the steam.

Waste Disposal

Vegetable Wastes. In selecting a site for a dehydration plant, careful consideration should be given to the problem of waste disposal. Plant effluents, if allowed to run into rivers or creeks or to flood waste lands, may soon cause trouble from stream pollution or by the creation of a public nuisance, followed by law suits and drastic action by public health and conservation authorities. Disposal of waste through a municipal system may cause overloading and complete failure of the system.

In the case of vegetable and fruit dehydration plants, the wastes will be both solid and liquid. The former will consist of trimmings and peelings, and might be classed as garbage. A plant handling 40 tons of potatoes per 24 hours will have about 10 tons of such waste, if they are peeled by abrasive machines. This represents the amount of garbage that would be obtained from a city of 50,000 people. It is thus apparent that the dehydrator will be called upon to dispose of his own waste, because it is unlikely that any municipal garbage-collecting system would be willing to undertake this additional load.

The garbage should not be allowed to accumulate in the plant, but should be disposed of promptly; otherwise it will attract flies and other insects, and rats. In warm weather it quickly ferments and creates offensive odors. If the garbage cannot be handled by municipal authorities, it may be disposed of by *sanitary fill.* In this method, the garbage is dumped in low places on waste lands. The material is placed in 12-in layers and each layer covered with 18 to 24 in of ashes or dirt. *Burial* is another method, in which trenches 3 ft wide and 12 in deep are dug and the garbage placed in the trenches, which are subsequently covered with the earth excavated from the next series of trenches. The garbage should be promptly covered before flies are hatched from the eggs and mag-

gots in the material before burial. *Dumping into water* can be used only if a large body of water is available, and in most cases this method is very costly and there is great danger of creating a nuisance. *Recovery of grease and burning,* although used in municipal systems, are too expensive to consider from the standpoint of the dehydrator.

The liquid wastes from a vegetable dehydration plant of the capacity mentioned above are roughly equivalent to the sewage flow of a town of 16,000 people. The waste will contain large quanti-

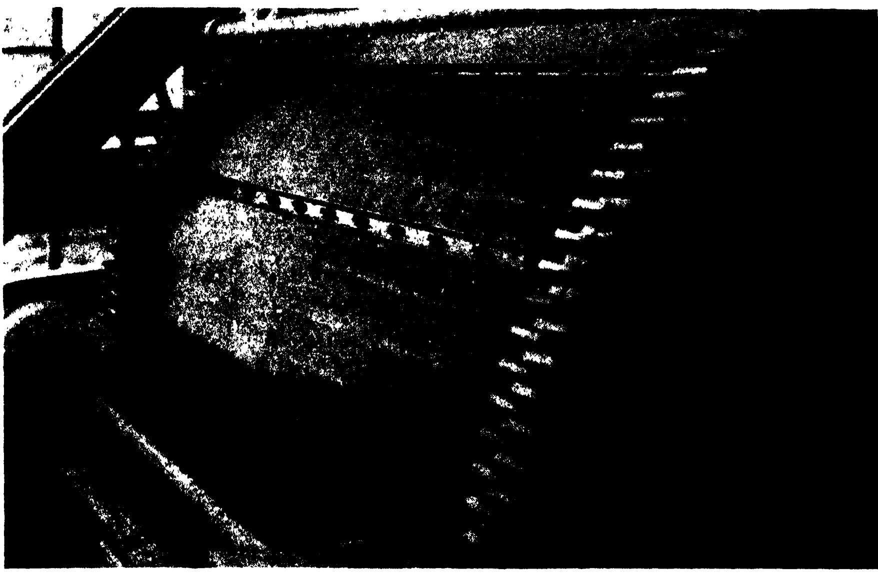


FIG. 40. Sewage Screen. This type of screen is suitable for screening effluents from dehydration plants.

ties of dissolved and suspended organic matter of an unstable nature. If these wastes are dumped into a small stream or drainage ditch, the water in the stream will be deprived of its dissolved oxygen, and anaerobic decomposition will result, giving rise to offensive odors; if there are fish or plants present in the stream they will soon die because of lack of oxygen. If pollution is very great, there will be sludge formations along the banks and at the stream bottom, bubbles of gas will be seen and there will be an increase of bacteria, algae, protozoa and crustacea which prey upon them. If, on the other hand, the liquid wastes are sufficiently diluted, thus increasing the dissolved oxygen, aerobic bacteria and higher forms

of life will be able to oxidize the organic matter without giving rise to offensive odors.

Liquid wastes from a plant processing 40 tons of potatoes per 24 hours will amount to about 120,000 gals. Economic considerations will not generally permit more than the most simple treatment of such wastes. Inasmuch as the waste contains suspended matter of various sizes, the material should first be passed through a screen of approximately 40 mesh. Such a screen may be con-

FIG. 41. Ponding of waste waters from a citrus drying plant. [From Nolte, von Loesecke and Pulley, *Ind. Eng. Chem.*, 34, 670 (1942).]

structed without too much difficulty and mounted on trunnions so that it will revolve. To prevent clogging, sprays of water should be directed upon the outside. Regular sewage screens may also be purchased, one such type being illustrated in Fig. 40. Other types are so constructed that they vibrate to prevent clogging.

The screened effluent will still contain suspended matter too fine to be removed by screening, and the material should therefore be pumped to settling tanks or basins. Retention time will be from 10 min to 2 hours, depending upon the rate of settling. Settling tanks may be of wood, or merely ponds dug from the earth (Fig. 41). This latter method is cheaper and does not call for any con-

struction material. It is preferable to have a series of ponds, as shown in the figure, so that the sludge can be removed from one series while the other is in use.

The effluent from the ponds should preferably be aerated before discharge into a stream. This can be accomplished by pumping through inverted spray nozzles of such type that a mist is obtained. The amount of effluent that can be discharged into a flowing stream without danger of pollution and creation of a nuisance will depend upon the dissolved oxygen content of the body of water into which it is to be conducted, as well as upon the dissolved oxygen content of the effluent. In water containing a normal amount of oxygen (approximately 3 to 5 ppm), the amount of sewage should not be more than one-twentieth to one-fortieth of the amount of water flowing.[2] Under no circumstances should the effluent from the plant be discharged into a stream without permission from the proper state or local authorities.

The sludge from the settling tanks or ponds can be mixed with the solid refuse from the plant and disposed of as garbage. Or it can be applied to waste lands, in which case it should be plowed under.

Disposal of Dairy Wastes. Satisfactory disposal of this type of waste is not so simple as that from vegetable or fruit dehydrating plants. Considerable work has been done in this field, and trickling filters seem to be the best method of treatment. Unfortunately, such filters require a considerable capital investment and operating costs may be high. The dairy industry has been investigating this problem for years and considerable progress has been made. For more detailed information dealing with the disposal of waste of this type, the reader should consult the following publications:

Eldridge, E. F., "Disposal of Wastes from Milk Products Plants," *Mich. Agr. Exp. Sta. Special Bull.* 272 (1936).

Roberts, C. R., "Progress in Milk-Waste Disposal," *Sewage Works J.*, **8**, 489 (1936).

Galligan, W. E., and Levine, M., "Purification of Creamery Wastes on Filters at Two Iowa Creameries," *Iowa State Coll. Exp. Sta. Bull.* 115 (1934).

[2] Ehlers, V. M., and Steel, E. W., "Municipal and Rural Sanitation," 2nd Ed., p 44, McGraw-Hill Book Co. Inc., New York, 1937.

Sanitation Within the Plant

Water Supply. Water used in the plant should be of potable quality and comply with the U. S. Public Health Service Standards.[3] If the water is obtained from a private source, periodic tests must be made to maintain its sanitary quality.

In addition to water used for washing and flushing, a plentiful supply will also be needed for drinking purposes. Water for washing and flushing in a vegetable dehydrâtion plant will amount to about 3000 gals per ton of vegetables processed; water for drinking purposes is usually estimated as about 20 gals per person per working day. Thus, a plant processing 40 tons of vegetables per day of 24 hrs should have a potable water supply capable of delivering 120,000 to 125,000 gals per 24 hrs. In addition to this, water should be available for fire protection. In this connection, there is occasionally the tendency to use water from an unsafe supply for this purpose. Such a practice is frowned upon by health authorities because of the danger of careless workers drinking the water; or sometimes the auxiliary fire supply is accidentally cross-connected to the main supply, thus contaminating the latter.

Drinking water is preferably supplied by means of drinking fountains of approved type. Usually one fountain for every 100 workers will be sufficient, although this will vary from 1 to 50 to as few as 1 to 200.

Toilets. Adequate toilet facilities should be provided, and should be well ventilated, illuminated, and the floors constructed of concrete or tile so that they may be flushed. Water closets, lavatories and sinks should be of such a type that they can be easily cleaned. One toilet is generally furnished for every 15 employees, and one urinal for every 20 male employees. Wash bowls should not have plugs so that the bowl cannot be filled. In small plants, one wash bowl to every three employees will be found sufficient. Where showers are considered desirable, one for every 25 employees is adequate.

Locker rooms are considered necessary so that employees can change from their street clothes into their work clothes. Some public health authorities consider it desirable to combine the locker rooms

[3] "Drinking Water Standards," *Public Health Repts.* **58,** No. 3, p. 75 (1943) U. S. Public Health Service, Washington, D. C.

with the toilet, and each employee should have his own locker so constructed that it is well ventilated. In some plants, the workers hang their work clothes on hooks suspended from the ceiling so that air may be free to circulate about the clothing. This practice is suitable for steel or manufacturing plants, but it does not seem desirable in a food-processing plant.

Toilets and locker rooms should be kept clean, and the most satisfactory manner for doing this is to assign a janitor whose sole responsibility is the sanitary condition of this part of the plant.

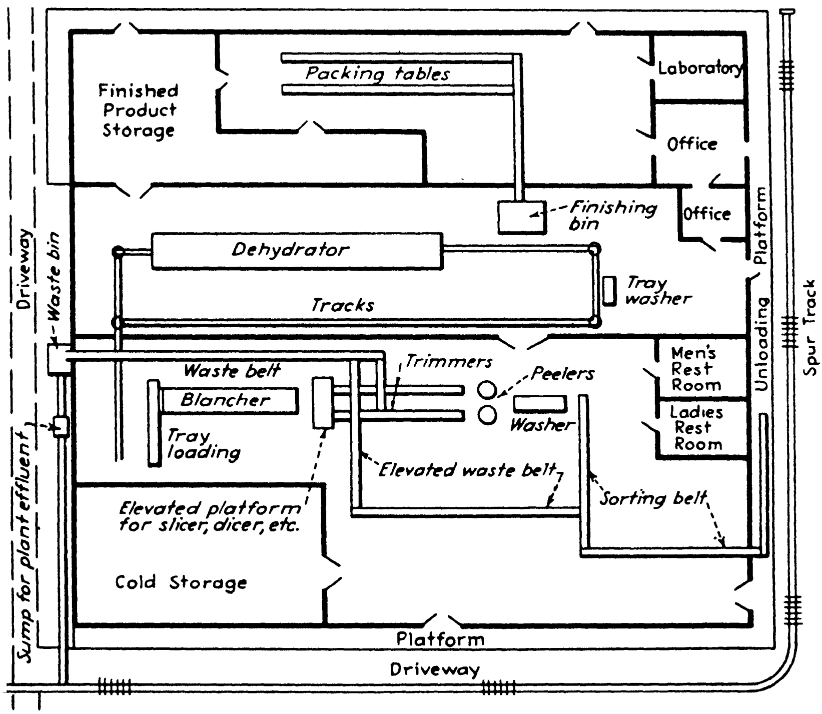


FIG. 42. Sketch of layout of vegetable dehydration plant. (Not drawn to scale).

Medical Examination of Food Handlers. It goes without saying that all persons preparing and handling food should be free from communicable diseases. Unfortunately, medical certificates are sometimes issued after only the most perfunctory examinations, and even in cases where physical examinations are properly made, the certificate indicates the health of the employee only at the time of examination. The employee might become infected a few hours

after passing the examination and become a nucleus for spreading infection. It is difficult, if not impossible, to avoid this situation entirely, but attempts are made to do so by requiring that health certificates be renewed every six months.

In examining food handlers, evidence is sought for tuberculosis, typhoid fever, syphilis, gonorrhea and sometimes diphtheria.

Cleanliness of Employees. Employees should not be permitted to work in their street clothes, but should be required to wear suitable, clean work clothes. Female employees who do trimming of vegetables, pitting of fruit or breaking-out of eggs should be required to have clean finger nails. Some large food plants provide experienced manicurists to see that nails of female employees are kept in the proper condition. Finger-nail enamel should be discouraged: the material is likely to chip and get into the food being handled. Some people are subject to infection about the nails, especially if the hands are constantly wet or in contact with weak acids, alkalies or certain volatile oils. Such employees should be required to wear rubber gloves.

Employees should not be allowed to eat their lunch in the plant proper, but in a special room provided for this purpose.

Rodent Control. In common parlance, "rodent" is confined to mice and rats, but from the standpoint of public health the term covers various field mice, cotton rats, pocket gophers, prairie dogs and ground squirrels. The most destructive rodents are four different species: the house mouse, brown (Norway), black and roof rats. These rodents are likely to become infected with bubonic plague which is transmitted from rat to rat through the bite of fleas with which they are normally infested. Plague may be transmitted to man, as history has told. Rats also serve as a reservoir for typhus, infectious jaundice, tapeworms, and other intestinal parasites. Besides the danger of spreading disease, rodents in the United States destroy crops and other personal property valued at two hundred million dollars each year. Rodents are controlled by poisoning, fumigation, viruses, rat-proofing and elimination of food.

Poisoning is most effective, using a bait of barium carbonate (1 part of barium carbonate to 4 parts of ground meat or cereal). Small amounts of the mixed bait are put in small paper bags, the necks of the bags closed by twisting and the bait scattered in

the vicinity of rat holes, or in the open if there are no domestic animals about. Uneaten bait should be removed each morning. Powdered squill (1 part of squill to 16 parts of meat or cereal) is also sometimes used, and has the advantage of being non-toxic to humans, dogs, cats and fowls.

Trapping may be effective as a control method, but some species of rats are shy of traps, though they will readily take poisoned bait. Cheap "snap" or "guillotine" traps are the types most commonly used. Wire traps that catch the rats alive are useful only if the rodent is to be inspected. Effective baits include cheese, bread smeared with bacon grease, meat, fish and orange or grapefruit seeds. The traps are set in runways or in sheltered places where the rat is likely to hide.

Fumigation is used to rid ships of rats, but is not generally used in food establishments. Hydrocyanic acid gas is used; it is extremely toxic and under no circumstances should fumigation be attempted by an inexperienced person; nor should this gas be used if there is a possibility of its being absorbed by food. Most foods that have been exposed to cyanogen will retain residual gas in quantities that may be toxic.

Carbon monoxide is also sometimes utilized, but whereas the presence of even small amounts of cyanogen may be readily detected by its characteristic almond-like odor, carbon monoxide is odorless and cannot be readily detected before injurious or fatal effects have resulted.

The disadvantage of fumigating is the probability that the rats will die in the walls and create offensive odors.

Rat-proofing. Poisoning, trapping and fumigation are of little value in rodent control unless carried on continuously. Rat-proofing is the most effective measure for keeping rats out of a building. Space will not permit a detailed discussion of this subject and the reader should consult:

Information Concerning Rat Surveys and Rat-Proofing. *Reprint 260, Public Health Rpts.* Nov. 5, 1920, U. S. Public Health Service, Washington, D. C.

Ehlers, V. M., and Steel, E. W., "Municipal and Rural Sanitation," 2nd Ed. pp. 204-208, McGraw-Hill Book Co. Inc., New York, 1937.

Fly Control. The common house fly spreads disease by mechanical means, *i.e.*, its hairy body and legs become covered with the filth upon which it crawls, to be deposited later on food. Flies are impli-

cated in the spread of smallpox, ophthalmia, parasitic worms, intestinal diseases, enteritis, cholera and infantile diarrhoea. Besides the common house fly, the biting stable fly may be a factor in spreading such diseases as anthrax, relapsing fever, horse sickness and other infections. Fruit flies (vinegar flies) are small insects seen around decaying fruit or where vegetables are being pickled. Because of their small size, when they alight on moist food they are very often unable to fly away but stick to the food. Besides spreading filth, they are particularly irritating, swarming about the heads of food handlers and getting into the ears, nose and eyes.

The best method of fly control is prevention of breeding, and destruction of larvae. Garbage that has been improperly disposed of is an ideal breeding site. Such breeding places may be treated with borax applied at the rate of about one pound per 16 cu ft and the garbage then hosed down. The borax may also be applied as a solution. According to Ehlers and Steel,[2] kerosene, iron sulfate, potassium cyanide, copper sulfate, lime-sulfur, paris green, sodium fluoride and formaldehyde are useless as larvicides.

Food plants should be properly protected with 18-mesh screens. Traps are also useful to keep down the fly population, the most economical trap being the conical-hoop type as described by Bishopp.[4] This consists, briefly, of a cone of screen wire with a hole at the apex of the cone. The cone is placed inside of a cylinder also of screen, and so arranged that the base of both cylinder and cone are about an inch above the ground. The bait, usually blackstrap molasses, is placed in a pan on the floor beneath the apex of the cone. After feeding on the bait, the flies crawl up the cone in an attempt to escape and are caught in the cylinder. When the trap is filled, the flies are killed by immersing in boiling water.

Fly sprays usually consist of a kerosene extract of pyrethrum flowers, and an essential oil to give the spray a more pleasant odor. A satisfactory spray may be prepared by soaking one pound of pyrethrum flowers in one gallon of odorless kerosene for 48 hours, and then filtering. To the filtrate is added an essential oil, such as oil of wintergreen or cassia, in sufficient amounts to give an agreeable odor. Ordinary kerosene can be used in place of the odorless, but it will be more difficult to mask the odor.

[4] Bishopp, F. C., "Fly Traps and their Operation," *U. S. Dept. Agr. Farmer's Bull.* 734.

Bacteriological Aspects of Dehydrated Foods

Most organisms will not thrive at such low moisture contents as found in dehydrated foods, and in fact will tend to disappear. However, there are instances in which bacteria have been known to grow in media of low moisture content. But such organisms are soil bacteria native to the food products themselves, and it is extremely unlikely that pathogenic organisms would be capable of surviving, much less multiplying, in dried foods having a low moisture content. The proof of this statement awaits conclusive evidence.

Bacteria in Dehydrated Vegetables

In preparing vegetables for dehydration, they are washed, blanched in steam or hot water, and dried at temperatures ranging from about 120 to 165° F; all these operations, if properly executed, tend to decrease the bacterial population. Organisms that have been subsequently found in the dried product are classed by Prescott [5] as follows:

(1) Those originally present which have survived the process (or perhaps increased).
(2) Those gaining access from wash water, handling in the raw state, or from utensils.
(3) Those deposited on surfaces during packaging, handling in the dried state, or from utensils.

Prescott [5] examined a large number of dried vegetables and found none of them to be sterile. Some of his data are shown in Table 40. Prescott does not state whether these vegetables had been blanched prior to drying. Practically all the organisms found were unobjectionable and were of the soil or water type, the latter predominating. The high count in the case of soup mixtures is probably caused by the fact that such a mixture contains several different vegetables, all dried separately and thus subjected to considerable handling.

Later, Prescott, Nichols and Powers [6] reported further results of the examination of freshly dehydrated vegetables, as indicated in Table 43. In examining these data, there is no apparent correlation between the commodity and its bacterial population, nor is there

[5] Prescott, S. C., "Some Bacteriological Aspects of Dehydration," *J. Bact.*, 5, 109 (1920).
[6] Prescott, S. C., Nichols. P. F.. and Powers, R., "Bacteria and Molds in Dehydrated Vegetables," *Am. Food J.* 17, No. 6, 11 (1922).

a correlation between the moisture content of the product (within the limited range of moisture content reported) and the number of bacteria.

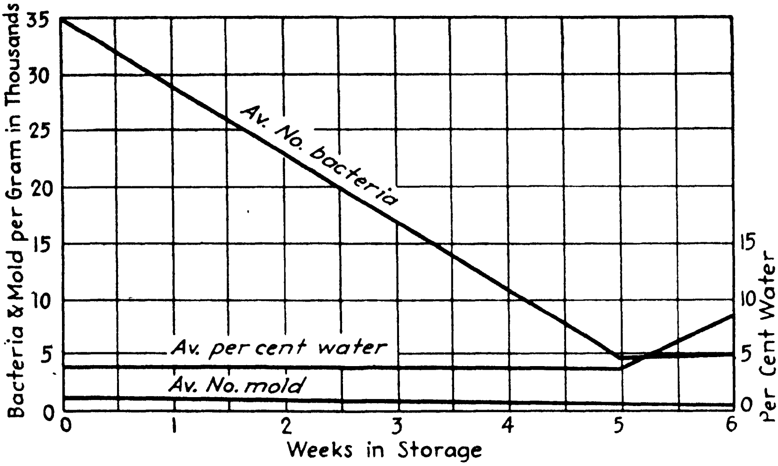


Fig. 43. Average number of bacteria and molds on dehydrated vegetables during storage in cardboard cartons at 68° F and 70% relative humidity. Products slowly absorbing moisture. (After Prescott, Nichols and Powers).

The more common types of organisms found by Prescott, and Prescott, Nichols and Powers, are given in Table 41.

Table 40. Bacterial Count of Commercially Dehydrated Fruits and Vegetable (*Prescott*)

Material	Moisture (%)	Organisms per gram* Plain agar	Glucose agar	Litmus glucose agar	Molds
Potatoes	3.14	9,400	9,800	3,800	60
Carrots	4.42	23,000	24,000	8,600	20
Cabbage	5.93	32,000	340,000	240,000	600
Turnips	5.62	220,000	300,000	20,000	20
Mixed vegetables	5.60	1,600,000	2,000,000	2,000,000	80
Turnips	5.0	3,800	7,000	3,000	
Cabbage	6.24	7,000	8,000	2,800	200
Onions	5.73	2,200	2,400	1,000	<20
Potatoes	2.78	6,800	6,900	1,500	<20
Tomatoes	3.32	26,000	5,000	1,000	<20
Beets	3.65	700	800		60
Bananas	4.72	600	600		<20
Sweet potatoes	4.42	100	900		100
String beans	4.27	600	800		<20
Peaches	2.79	800	200		40
Carrots	5.85	80	200		<20
Onions	4.03	400	6,000	2,000	400
Parsnips	4.09	4,400	18,000	10,000	60
Turnips	7.08	60	180		<20
Potatoes	2.69	400	1,200		440

*48-hr count at 37° C. < = less than.

Table 41. Types of Organisms Found on Dehydrated Vegetables
(*Prescott; Prescott, Nichols and Powers*)

Bacteria*	Molds†
B. vaculatus, B. denitrificans, B. lustigi, B. cuticularis, B. weichselbanini; Ps. cohaera, Ps. sinuosa, B. subflavus, B. tenacatis, B. ginglymus, Bact. mycoides, M. radiatus, Ps. viridescens, B. ambigua.	*Aspergillus, Mucor, Penicillium Spicaria, Sporotrichum, Trichoderma, Herpocladiella.*

* The names are given as set forth by the investigators, and no attempt has been made to change them according to the newer bacteriological terminology.
† The investigators indentified the molds as to genus, and no special effort was made to determine the species.

A clearer picture of the variety of molds present on the different vegetables may be obtained from Table 42.

Table 42. Varieties of Molds Present on Different Vegetables
(*Prescott, Nichols and Powers*)

Dried Commodity	Molds isolated
Potatoes	*Aspergillus, Penicillium, Mucor, Trichoderma, Sporotrichum, Spicaria.*
Carrots	*Aspergillus candidus, A. niger, A. fumigatus, Mucor, Trichoderma, Spirotrichum, Spicaria.*
Turnips	*Aspergillus, A. oryzae, penicillium, Herpocladiella.*
Tomatoes	*Aspergillus, Mucor, Trichoderma.*
Soup mixture	*Aspergillus, A. wentii, Mucor, Trichoderma, Thamnidium.*
Onions	*Aspergillus, Mucor.*

The danger of outbreaks of food infection or poisoning through the use of dehydrated foods has been studied by Prescott [5] in the case of vegetables. His experiments should be considered preliminary. In laboratory tests, Prescott inoculated stringless beans, parsnips, tomatoes and spinach with pure broth cultures of *E. coli, Eberthella typhosus, B. paratyphosus* A and B, *B. enteritides, B. paracoli, B. subtilis* and *B. welchii.* The vegetables were dried at 80° C (176° F) for 4 hours. *B. subtilis* was found to have survived dehydration, while organisms resembling *Eb. typhosus* and the paratyphoid forms in some respects, but not typical, were found. In another experiment, organisms typical of *Eb. typhosus* were recovered from inoculated food dried under the same conditions as the first experiment. The positive presence of *Eb. typhosus* or the paratyphoid group was not confirmed because serum and animal tests apparently were not completed when the results were reported.* To test the survival of organisms under actual working

* Prescott states, "Serum tests and animal tests may therefore prove the surviving types to be entirely different from the organisms used." *J. Bact.*, 5, 124 (1920).

conditions in a dehydration plant, Prescott inoculated carrots, cabbage and potatoes with broth cultures of *Eb. typhosus*, B. *paratyphosus* A and B, *B. suipestifer*, *B. murisepticum*, *B. enteritidis*, *E. coli*, *B. paracoli*, *B. welchii*, *Cl. botulinus*, *Microspira protea* and *Micrococcus pyogenes aureus*. After dehydration of the vegetables,

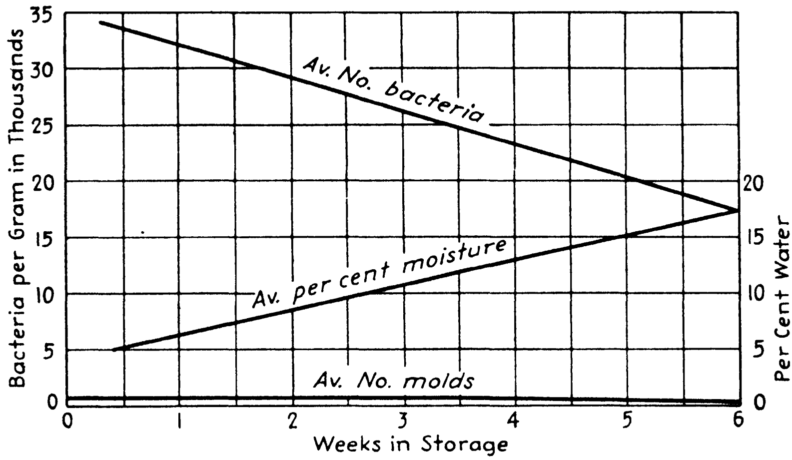


FIG. 44. Average number of bacteria and molds in dehydrated vegetables during storage in cardboard cartons at 32° F, 95% relative humidity. Product rapidly absorbing moisture. (After Prescott, Nichols and Powers).

all the organisms were found to have been destroyed. Prescott points out, however, that the results must be regarded as preliminary. It would seem that further research should be done in this field.

Table 43. Bacteria and Molds in Freshly Dehydrated Vegetables
(*Prescott, Nichols and Powers*)

Commodity	No. bacteria per gram*	No. of molds per gram*
Sliced beets	160,000	400
Shredded cabbage	173,500	600
" "	8,500	200
" "	110,000	400
" "	400	2,000
" carrots	20,500	20
" "	14,000	20
" "	40,000	600
Sliced "	200	2,000
Sliced onions	300,000	20,000
" "	1,200	2,000
" potatoes	8,800	60
Quartered "	6,300	20
Sliced "	63,000	200
Spinach	670,000	2,000

* 48-hr count at 37° C.

Nichols,[7] working with dried fruit, did not find pathogens; but of the samples examined, none was sterile. In general, the low moisture and high sugar content of dried fruit inhibit the growth of microörganisms, and they remain dormant until subject to more favorable conditions.

In 1928 Hunwicke and Grinling,[8] working in England, traced an outbreak of colitis to French packaged dates. They isolated the causative organism which they called *B. coli tropicalis,* the description of which resembles very closely that of *E. coli.* Hunwicke and

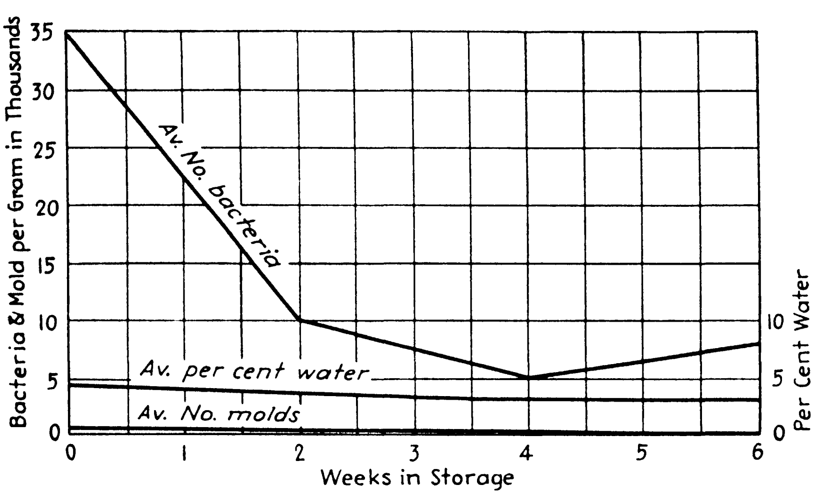


FIG. 45. Average number of bacteria and molds in dehydrated vegetables during storage in friction top tin cans and cardboard cartons at 68° F, average relative humidity. Products constant in moisture content. (After Prescott, Nichols and Powers.)

Grinling concluded that dates may readily be contaminated during repacking (because none of the bulk dates they examined showed any intestinal bacteria) and that the presence of coliform organisms on the surface of packed dates constitutes a public health problem.

Fellers,[9] noting the implications of Hunwicke and Grinling's work, made bacteriological examinations of dried fruits found on American markets. Variation in the number of microörganisms was very great: some samples were sterile, and others contained as

[7] Nichols, P. F., "A Brief Summary of Activities of the U. S. Department of Agriculture in Dehydration," *Month. Bul. Dept. Agr. Calif.*, 9, 133 (1920).

[8] Hunwicke, R. F., and Grinling, G. N., "A Note on Some Intestinal Bacteria Isolated from Dates," *Lancet* (London), 214, 1071 (1928).

[9] Fellers, C. R., "Pasteurized Dried Fruits," *Am. J. Public Health,* 20, 175 (1930).

many as 100,000 organisms per gram. Of 79 samples examined, only 8 contained lactose fermenters; none of these was identified as *E. coli,* though several closely resembled *Aerobacter aerogenes.* Sixty of the samples showed no yeast, a fact which Fellers states is difficult to explain. However, this may have been due to the sulfur treatment of such fruit. Anaerobic bacteria were present in about half the samples, but in small numbers. Relatively abundant bacteria included *cocci,* especially *Sarcinae* and *Micrococci.* Molds were all common saprophytes, with Aspergilli most numerous. The bacterial flora on fruits seem to differ from those on vegetables, if we compare the findings of Fellers with those of Prescott and his co-workers. Fellers further points out that bulk-dried fruits harbored more microörganisms than packaged.

Table 44. Microörganisms in American Dried Fruits as Purchased

(*Fellers*)

Dried fruit	No. of samples	Av. moist. content (%)	Bacteria per gram	Molds per gram	Yeast per gram	No. of samples contg. lactose fermenters
Dates, Iraq bulk	8	16.1	12,300	18,400	20	3
Dates, Iraq packaged	12	17.1	3,970	35,800	55	2
Dates, Iraq commercially pasteurized	16	19.4	80	700	0	0
Dates, Iraq laboratory pasteurized	8	20.6	65	160	0	0
Dates, Calif. packaged	2	15.6	760	700	100	0
Dates, Calif. glass-packed	2	44.0	320	0	0	0
Dates, French Algerian packaged	1	24.0	18,000	42,000	16,000	1
Figs, Smyrna packaged	2	9.6	420	20	3	0
Figs. Calif. packaged	2	15.1	210	200	10	0
Figs, Smyrna laboratory pasteurized	2	19.8	20	10	0	0
Prunes, bulk	2	15.0	25	15	0	0
Prunes, packaged	2	16.3	15	6	0	1
Prunes, laboratory pasteurized	1	20.6	0	2	0	0
Peaches, bulk, sulfured	1	13.3	10	0	0	0
Peaches, packaged sulfured	1	15.1	6	0	0	0
Raisins, seedless	6	15.3	310	340	6	1
Raisins, seeded	2	17.1	40	90	0	0
Currants, packaged	2	17.3	95	105	0	0
Apricots, bulk, sulfured	2	11.8	8	17	0	0
Apricots, packaged sulfured	2	13.9	20	0	0	0
Apples, bulk sulfured	2	21.9	40	10	10	0
Cranberries, packaged	1	6.0	0	3	0	0

As a result, pasteurization of packaged fruits was recommended. The most effective pasteurizing temperatures found were from 150 to 185° F for 30 to 70 min at relative humidities of from 70

to 100 per cent. The wide variation of temperature given is due to the fact that different treatments are required for each fruit, and often for each variety. Both *E. coli* and *Eb. typhosus* were destroyed where the temperature of the packaged fruit remained at 160° F or above for 30 min and at relative humidities of 75 per cent or more.

Table 45. Bacterial Population of Spray Dried and Drum Dried Milk (*Hunziker*)

Reference	Source of Powder	Bacteria per gram
	Spray-dried	
a	Powder direct from drying chamber	10,000 to 15,200
b	Made from pre-condensed milk	15,600 to 595,000
b	Same process, but not condensed	1,500,000 to 3,500,000
c	Krause process	5,000 to 30,000
d	Domestic brands	4,400 to 5,500,000
d	Foreign brands	5,400 to 3,100,000
	Drum Dried	
a	Just-Hatmaker process, direct from drums	70 to 300
a	Same, after powdering	5,940 to 14,600
b	Modified Kunick process	16,900 to 626,000
e	Just-Hatmaker process	4,000 to 5,400
f	Just-Hatmaker process, whole milk	4,000 to 5,000
f	Just-Hatmaker process, skim milk	2,200 to 6,000
g	Just-Hatmaker process	800 to 6,400
h	Just-Hatmaker process direct from drums	45 to 80
h	Just-Hatmaker process from collecting boxes	750 to 1,250
i	Just-Hatmaker process direct from drums	561
i	Just-Hatmaker process after sifting	1,614
i	Just-Hatmaker process after packing	3,271
d	Domestic brands	40 to 2,200
d	Foreign brands	240 to 7,900

(a) Delepine, *Rept. Loc. Govt. Board Pub. Health and Med. Subj. Food Repts.* 21, London, 1914.
(b) Downs, Thesis, Cornell, 1920.
(c) Tillmans and Strohecker, *Z. f. Untersuch. d. Nahr. u. Genussm*, 47, 420 (1924).
(d) Macy, H., *J. Dairy Sci.*, 11, 516 (1928).
(e) Grosso, G., *Z. f. Fleisch. u. Milchhygiene.*, 17, 312 (1907).
(f) Hoffman, W., *Arch. f. Hyg.* 59, 216 (1906).
(g) Hueppe, F., *Zentralbl. f. Bakt. I. Abt. Orig.* 64, 34 (1912).
(h) Kossowicz, A., *Z. Landw. Versuchsw. Oesterr.*, 11, 719 (1908)
(i) Supplee, G. C., and Alsbaugh, V. J., *J. Dairy Sci.*, 5, 2 (1922).

Bacteria in Dry Milk

Dry milk, if properly manufactured from clean milk and properly stored, is, in general, low in bacterial population; and because of deficient moisture the bacteria present cannot multiply and will actually decrease. Bacteria present in the dry product are those able to survive the drying, or those introduced during packaging.

As would be expected, drum-dried milk contains less bacteria than spray-dried because of the high temperatures used in the former method. Table 45 shows bacterial counts of dried milk as assembled by Hunziker.[10]

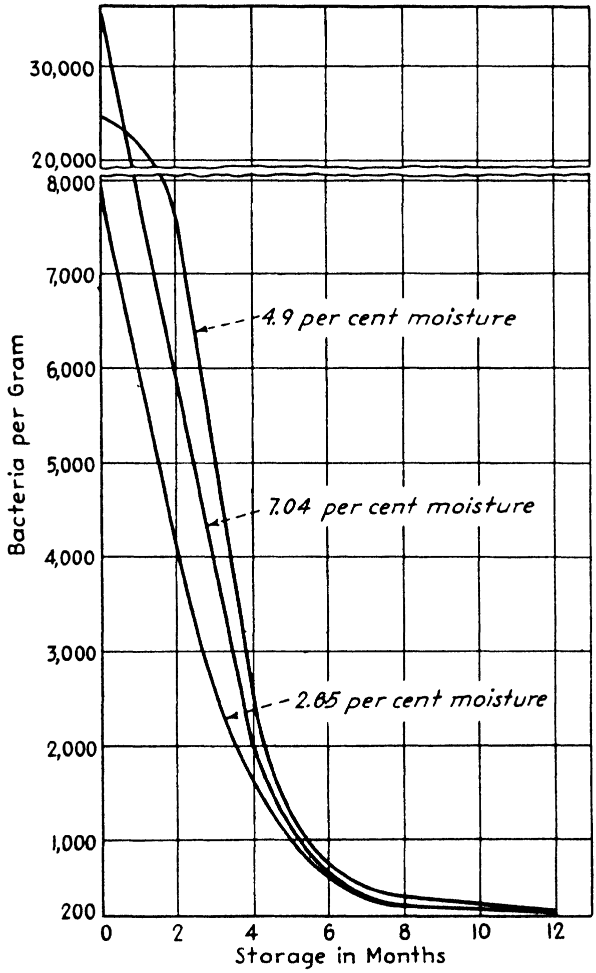


FIG. 46. Bacterial counts of dry milk when fresh and after storage. (Plotted from data of Supplee and Alsbaugh).

In Fig. 46 are plotted data of Supplee and Alsbaugh[11] showing the decrease of bacteria in stored, dry milk. Macy[12] has

[10] Hunziker, O. F., "Condensed Milk and Milk Powder," 5th Ed. p. 544, Published by the author, La Grange, Ill., 1935.

[11] Supplee, G. C., and Alsbaugh, V. J., "Bacterial Content of Milk Powder," *J. Dairy Sci.*, 5, 2 (1922).

[12] Macy, H., "Some Observations on the Bacterial Content of Dried Milk," *ibid.*, 11, 516 (1928).

shown that this decrease in bacterial population is more rapid at high temperatures than at low in spray-dried milk, but is not of significance in drum-dried milk. Macy points out that this is probably due to the fact that only the resistant types of organisms are able to survive the high temperatures used in drum-drying, while in the case of spray-drying, the less resistant forms survive, only to die during subsequent storage.

The bacterial flora of dry milk have been investigated by Delepine,[13] Supplee and Alsbaugh (*loc. cit.*), Hunwicke and Jephcott,[14] Jephcott, Hunwicke and Ratcliff,[15] and Macy (*loc. cit.*). The results of all these workers closely agree. In spray-dried milk, acid-formers predominate; in drum-dried, surviving organisms are largely spore-formers of the *B. mesentericus* and *B. subtilis* types. Coccus forms, and yeast and mold may also be present in spray-dried milk. *B. tuberculosis* is either destroyed or rendered avirulent by drum-drying, but data do not appear to be available regarding the fate of this organism in the spray-drying of milk. Jephcott, Hunwicke and Ratcliff point out that the study of the number and type of bacteria in drum-dried milk furnishes an index to the purity of the dry milk.

Bacteria in Dried Eggs

Normally, new-laid eggs are free from bacteria. Careless handling, such as improper washing, or allowing them to sweat when taken from storage will permit bacterial access to the eggs through the shell pores. There are instances, however, in which new-laid eggs contain a high bacterial population. This is due to infection of the oviduct, and bacteria have been found present in the oviduct of the hen, even in the upper portions. The egg thus can become infected in the earlier stages of its formation. A diseased condition of the ovary of the hen may also cause infection.

Infection of the egg through its shell is prevented by a substance in egg white called "lysozyme," which is germicidal to pathogenic

[13] Delepine, S., "The Effect of Certain Condensing and Drying Processes Used in the Preservation of Milk upon its Bacterial Contents," *Rept. Loc. Govt. Board of Pub. Health and Med. Subj. Food Repts.*, 21 London, 1914.

[14] Hunwicke, R. F., and Jephcott, H., "The Destruction of Bacteria in the Roller Process of Milk Drying," *J. Dairy Sci.*, 8, 3 (1925).

[15] Jephcott, H., Hunwicke, R. F. and Ratcliff, N., "The Attainment of Bacterial Purity in the Manufacture of Dried Milk," *Proc. World's Dairy Congress*, Washington, D. C., 1923.

and other types of organisms. Unfortunately, lysozyme loses its potency as the eggs are stored.

In order to keep the bacterial count of dried eggs as low as possible, it is important to start with eggs that are low in this respect. Thus, DeBord[16] obtained a bacterial count of 350 per gram in dried eggs from clean eggs, compared with 1,160,000 for bad eggs. Starting with clean eggs, the product should be handled in a clean, sanitary manner. All utensils and equipment should be thoroughly washed and then steamed. It is important that washing be well executed because if dirty equipment is steamed, the dirt will be baked to the utensils and render cleaning and sterilization impossible.

Table 46. Bacterial Count of Dried Egg Products

Authority	Product	Bacteria per gram
Pennington, *et al.*[a]	Flaky dried eggs	65,000 to 20,000,000
Pennington	Flaky dried eggs	E. coli, 0 to 1,000,000
Marcardier and Goiyon[b]	Dried whole eggs	10,000
Wyant[c]	Dried whole eggs	40,000 to 60,000
DeBord[d]	Spray-dried whole eggs	350 to 1,160,000
DeBord	Spray-dried whole eggs	45,000 to 2,400,000

[a] *U. S. Dept. Agr. Bull.* 224 (1916).
[b] *Ann. Fals.*, 13, 96 (1920).
[c] *Mich. Agr. Exp. Sta. 59th Rept.*, p. 1920 (1922).
[d] *J. Agr. Res.*, 31, 155 (1925).

Goresline[17] points out that the significance of bacteria in eggs and egg products in relation to public health has never been fully established. However, the presence of *E. coli* in large numbers may be taken as an indication of careless processing. This organism also tends to remain viable during the storage of dried eggs. Bacterial growth will not occur in properly dried eggs stored at 30° C (86° F) unless the relative humidity exceeds 90 per cent, and the organisms die in greater numbers as the moisture content of the product is reduced below 5 per cent.

Dried whole egg should not contain more than 300,000 viable organisms per gram.

Table 46 shows the bacterial count of dried egg products as found by different investigators.

[16] DeBord, G. C., "Effect of Dehydration upon the Bacterial Flora of Eggs," *J. Agr. Res.*, 31, 155 (1925).
[17] Goresline, H. E., "Eggs and Microbiology: Eggs and Egg Products," *U. S. Dept. Agr. Circ.* 583 (1941).

Types of organisms that have been isolated from dried whole eggs include *E. coli, Staph. citreus, B. subtilis* and *Penicillium.*

In the preparation of egg white by the usual fermentation method it is, of coürse, impossible to maintain minimum bacterial count. The finished product should, however, be free from objectionable bacteria.

The literature does not report cases of food poisoning from dried egg products, although there are cases recorded of outbreaks of poisoning from consuming shell eggs.

Bacteria in Salted and Smoked Fish

Fish may be readily preyed upon by bacteria, and the greater the length of time between catching and marketing or preparation, the greater the bacterial count. As already stated, the fish are covered with slime which harbors heterogeneous flora belonging to those groups found chiefly in water, *e.g., Achromobacter, Flavobacter,* and *Pseudomanas.* Gutted fish are more liable to bacterial decomposition than those that have not been opened, because evisceration exposes the tissues to more ready attack by microörganisms.

The smoking of fish aids in its keeping qualities because of the presence of formaldehyde in the smoke. Investigations by numerous workers have shown that smoking does cause a reduction in bacteria and that the more concentrated the smoke, the greater the reduction. In general, spores are resistant to smoke, the resistance increasing with the age of the spores.[18]

Outbreaks of infection have been traced to consuming smoked and salted fish. As an example, in 1920 there were 300 severe cases of febrile gastro-enteritis in Kiel, Germany caused by eating smoked mackerel.[19] The symptoms were vomiting, fever and severe diarrhoea. The fish was alleged to have been infected with *Salmonella enteritidis.* In 1919, a death from eating salted herring was reported in Germany.[19] The herring had a rancid odor, and the death was reported to have been caused from botulism. *Cl. botulinium* was cultivated from two of the herring involved.

[18] Tanner, F. W., "The Microbiology of Foods," 1st Ed., Twin City Publishing Co., Champaign, Ill., 1932.

[19] Tanner, F. W., "Food-Borne Infections and Intoxications," 1st Ed., Twin City Publishing Co., Champaign, Ill., 1933.

Bacteria in Meat

Meat shipped interstate is inspected by Federal inspectors of the Bureau of Animal Industry of the U. S. Department of Agriculture in accordance with a law passed by the Congress in 1906. Approximately 60 per cent of the meats consumed in the United States are produced in plants under Federal inspection, while the remaining 40 per cent are subjected to state and city inspection. Such meat is given both an ante-mortem and post-mortem inspection, the latter involving careful examination of every part of the carcass by trained veterinarians. If the examination indicates a healthy condition, the animal is marked "U. S. Inspected and Passed."

The possible bacteriological contamination of meat and its products cannot be gone into here. The bacteriology of dehydrated meat is still under investigation. It is known, however, that the precooking of meat before dehydration is sufficient to destroy any organisms capable of causing either food infection or food poisoning.

The destruction of *Trichinella spiralis* is particularly important in the case of dehydrated pork. Infestation of humans with this parasite causes trichinosis, a disease accompanied by fever, myositis (inflammation of muscle tissue), certain skin manifestations, and in severe cases anemia, delirium, pleurisy or pneumonia. Mortality in the United States is about 5 per cent, and the disease is more prevalent than hitherto suspected. Federal meat inspection does not include the examination of pork for these parasites because it would not be practical. Fortunately, the resistance of *Trichinella spiralis* to heat is not great and they are quickly destroyed at 55° C (131° F). Pork products that may be eaten raw are therefore heated to a minimum temperature of 58° C (137° F) if they are prepared in establishments under Federal inspection.

Bacteria in Dried Blood

The use of blood in foods makes it important that the blood be obtained only from healthy animals, and as free as possible from contamination. In this connection, blood cannot be collected in a clean manner from swine, and therefore should not be used for food purposes. It is generally believed that the blood and tissues of healthy animals may, at times, contain microörganisms. Cultures of blood from healthy live hogs, rabbits and guinea pigs have been

shown to contain staphylococci, other coccus forms, gram-positive and gram-negative rods, and bipolar rods. Just how these organisms enter the blood and other healthy tissues is still controversial.

In general, dried beef serum, prepared as already described, will have a lower bacterial population than dried eggs. The bacteria present tend to decrease when the product is stored in tight containers, this decrease being greater during storage at high than at low temperatures (Table 47).

Table 47. Bacterial Count of Dried Beef Serum Stored in Tin Cans
(Average moisture content: 6.0%)
(*von Loesecke, Unpublished data*)

Storage in Days	Bacteria per gram* when stored at— 51° F	68° F	98° F
0	170,000	170,000	170,000
36	10,000	60,000	170,000
52	30,000	10,000	10,000
95	60,000	10,000	10,000
123	160,000	8,000	30,000
160	160,000	80,000	9,000

* Nutrient agar at 37° for 48 hrs.

Suggested Readings

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Chapter 7

Costs of Dehydration

Dehydration costs are subject to wide variation, and this fact should be kept constantly in mind when interpreting cost data set forth in this chapter. Factors which particularly enter into the cost of dehydrating vegetables, and in some respects the dehydration of other commodities, are listed as follows:

(1) **Proper plant layout.** There should be proper balance between labor and machinery.

(2) **Labor costs.** These will vary in different parts of the country. In the cost data given for vegetables, male labor is on the basis of $0.75 per hr.; female labor, $0.60 per hr.

(3) **Raw material cost.** This is also related to preparation losses, as will be explained later.

(4) **Preparation losses.** These are related to labor costs as well as to raw material costs. A saving of 5 per cent, for instance, in preparation loss may justify the wages for a number of additional women per shift on a sorting or trimming belt.

(5) **Fuel costs.** In some sections of the country, it may be cheaper to use natural gas than fuel oil as a source of heat, depending upon the relative costs of the two utilities and whether oil can be obtained (Fig. 47).

(6) **Container cost.**

Dehydration of Vegetables

Labor Costs. In Table 48 are given labor costs for dehydrating seven vegetables now produced commercially. Under certain specific conditions, these figures will vary. Labor is based on $0.60 per hr for women, and $0.75 per hr for men. With the exception of small (5-ton plants) it has been assumed that the plant will operate 24 hrs per day.*

* In a 5-ton plant, preparation lines would be operated only 12 hrs per day. The capacities are based on the fresh, unprepared vegetable, and will vary according to the overall shrinkage ratio of the commodity.

Table 49 gives the cost of trimming per unprepared ton, and in Table 50 is indicated the cost per prepared ton of raw material and trimming labor, allowing for various preparation losses. It should

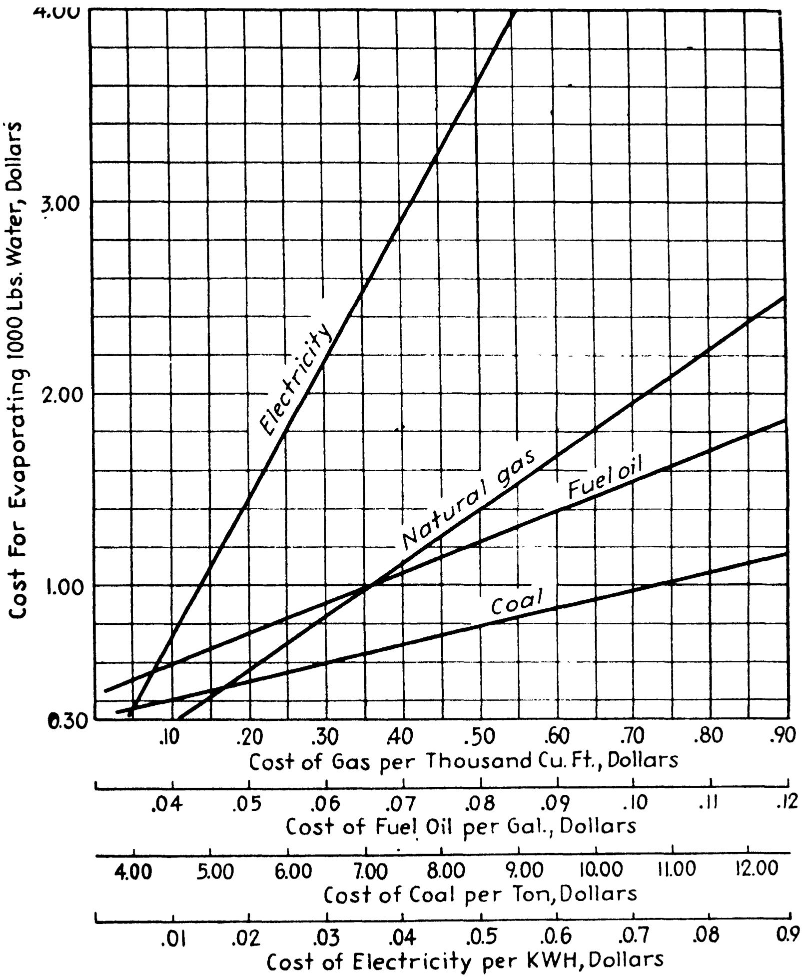


FIG. 47. Cost for evaporating 1,000 lbs. of water. In estimating these costs it has been assumed that: it will require 2,500 Btu per lb of water evaporated, that there are 160,000 Btu per gal of fuel oil, 900 Btu per cu ft of natural gas, 14,000 Btu per lb of coal and 3,412 Btu per kwh of electricity.

be pointed out that the hourly labor costs in Table 49 include overhead. Tables 49 and 50 should be used together in the following manner: Let it be assumed that the dehydrator purchases a shipment of potatoes at $50.00 a ton and has a preparation loss of 20

per cent. It is found that one woman, paid $0.80 per hr, can trim 80 pounds of tubers per hour. From Table 49 is obtained the cost of an unprepared ton of potatoes ($20.00), and to this figure is added

Table 48. Labor Costs for Dehydrating Various Vegetables in Plants of Different Sizes (*Dehydration Committee, Bur. Agr. Chem. & Eng.*)

Vegetable	Overall shrinkage	Plant Capacity (unprepared basis): 400 lbs per hr (5 tons per day)	830 lbs per hr (10 tons per day)	1670 lbs per hr (20 tons per day)	3330 lbs per hr (40 tons per day)	8330 lbs per hr (100 tons per day)
		Labor Cost per lb (cents)				
Beets	13:1	25.5	19.1	15.3	12.6	9.9
Cabbage	19:1	28.3	24.8	18.1	14.9	10.3
Carrots	10:1	17.9	14.6	11.2	9.7	7.7
Onions	14:1	20.5	15.9	13.5	11.3	9.4
Potatoes, white	7:1	14.7	12.5	10.9	9.8	8.2
Potatoes, sweet	4½:1	8.0	7.2	5.6	5.0	3.9
Rutabagas	10:1	17.9	15.3	11.6	9.8	7.7

Table 49. Cost of Trimming Per Unprepared Ton for Various Trimming Rates and Labor Costs*
(*Dehydration Committee, Bur. Agr. Chem. & Eng.*)

Trimming Rate. (lbs per hr)	Number of Women per Ton per Hr	Cost of Trimming Per Unprepared Ton for Various Labor Costs per Hour per Employee: $0.60	$0.80	$1.00
40	50	$30.00	$40.00	$50.00
60	33⅓	20.00	26.67	33.33
80	25	15.00	20.00	25.00
100	20	12.00	16.00	20.00
125	16	9.60	12.80	16.00
167	12	7.20	9.60	12.00
200	10	6.00	8.00	10.00
333	6	3.60	4.80	6.00
400	5	3.00	4.00	5.00
667	3	1.80	2.40	3.00

* Hourly labor costs include overhead.

Table 50. Cost per Prepared Ton for Raw Material, and Trimming Labor, Allowing for Various Preparation Losses
(*Dehydration Committee, Bur. Agr. Chem. & Eng.*)

Material and Trimming Cost per Unprepared Ton	Cost per Prepared Ton Allowing for Various Preparation Losses: 10%	20%	30%	40%
$20.00	$ 22.20	$ 25.00	$ 28.60	$ 33.30
40.00	44.40	50.00	57.20	66.70
60.00	66.70	75.00	85.70	100.00
80.00	88.90	100.00	114.30	133.30
100.00	111.10	125.00	142.90	166.70
120.00	133.30	150.00	171.50	200.00
140.00	155.60	175.00	200.00	233.30
160.00	177.80	200.00	228.60	266.70

the cost of the raw material, $50.00, giving a total trimming and raw material cost of $70.00 per unprepared ton. Now consulting Table 50, it will be found that this corresponds to $87.50 as the cost

of an unprepared ton (*i.e.*, under the 20 per cent trimming loss column the figure will be half way between $75.00 and $100.00). Let it be supposed, as another example, that the dehydrator purchased his potatoes for $40.00 per ton, and assuming they were poorer in grade than those selling at the higher price, there was a preparation loss of 30 per cent, and that trimming could be accomplished only at the rate of 40 lbs per woman hour. From Table 49, it is found

Table 51. Approximate Equipment Cost per Ton for Different Vegetables Handled per 24 Hours (unprepared basis)
(*Adapted from Data of Dehydration Committee, Bur. Agr. Chem. & Eng.*)

	Capacity of Plant (unprepared basis)				
Vegetable	400 lbs per hr (5 tons per day)	830 lbs per hr (10 tons per day)	1670 lbs per hr (20 tons per day)	3330 lbs per hr (40 tons per day)	8330 lbs per hr (100 tons per day)
Beets	$417.00	$377.00	$368.00	$281.00	$196.00
Cabbage	436.00	407.00	296.00	270.00	190.00
Carrots	556.00	444.00	358.00	293.00	224.00
Onions	258.00	264.00	238.00	212.00	139.00
Potatoes, white	468.00	587.00	405.00	345.00	254.00
Potatoes, sweet	628.00	512.00	467.00	371.00	272.00
Rutabagas	556.00	444.00	366.00	293.00	221.00

Table 52. Approximate Total Cost of Preparation Equipment for Plants of Different Capacities Handling Different Vegetables (unprepared basis)*
(*Adapted from data of Dehydration Committee, Bur. Agr. Chem. & Eng.*)

	Capacity of Plant (unprepared basis)				
Vegetable	400 lbs per hr (5 tons per day)	830 lbs per hr (10 tons per day)	1670 lbs per hr (20 tons per day)	3330 lbs per hr (40 tons per day)	8330 lbs per hr (100 tons per day
Beets	$2,000	$3,765	$7,350	$11,250	$19,575
Cabbage	2,095	4,065	5,925	10,080	18,975
Carrots	2,665	4,440	7,165	11,700	22,425
Onions	1,240	2,640	4,765	8,475	13,875
Potatoes, white	2,245	5,865	8,100	13,800	25,425
Potatoes, sweet	3,015	5,115	9,335	14,850	27,225
Rutabagas	2,665	4,440	7,315	11,700	22,125

*Costs include installation and accessory equipment. They do not include cost of building to house equipment, or cost of the dehydrater.

that the trimming cost is $40.00 per unprepared ton. Adding this to the raw material cost, there is obtained a total trimming and raw material cost of $80.00. Again consulting Table 50, it is found that $80.00 and a 30 per cent preparation loss gives $114.30 as the cost per ton of the prepared material. Thus, in this particular case it was more economical to buy the $50.00 potatoes.

Equipment Costs. For very small plants, cost of equipment may be as great as for plants of considerably larger capacity, because machinery to handle small amounts of material is not available,

Table 53. Preparation, Final Inspection and Packing Equipment and Labor Requirements in a Dehydration Plant Handling 100 Tons of White Potatoes per 24 Hours. (Unprepared Basis)

(*Dehydration Committee, Bur. Agr. Chem. & Eng.*)

Operation	Description of Equipment	Cost	Labor
Feeding the prep. line			3M
Washing	Drum washer. Drum size: 36″×12″, with 2 hp motor	$ 1,400	
Sizing	Rubber spool grader. Rolls 20″ wide. With ½ hp motor	400	1M
Peeling	Continuous peeler, 2 ea., with 3 hp motor. Standby peeler (batch) with 1½ hp motor	2,200 600	
Sorting and Trimming	Belt conveyor and sorter. Belt size 30″×75′, with 5 hp motor (two)	4,400	100F 1S
Stripping	Strip cutter and slicer with 2 hp motor (two)	1,400	
Spreading on blanching belt			2F
Washing	Sprays on front of end of blancher (this is included in blancher cost)		
Blanching	Wire belt blancher. Overall length, 52′. Covered area: 60″×42′. With 3 hp motor	5,200	
Tray loading and stacking	Rollers, scales and other loading equipment and small items. These are included in cost of accessory equipment (see below)		4F 4M
Moving cars and drying			3M
Scraping trays	Scraping done over end of conveyor		7M
Final inspection	Belt conveyor sorter. Belt size 30″×30′. With 2 hp motor	1,150	10F
Packing and preparing for shipment	Scales, table and sealing equipment	200	3F 5M
General: Foreman			1M
Helpers, cleanup, washing trays, and maintenance			9M
Subtotal		$16,950	
Add 40% for installation and accessory equipment; 50% for same, plus improvised items	50%	8,475	
Total		$25,425	
Equipment cost per ton handled per 24-hour day (unprep. basis)		$254.00	
Labor Cost per Pound (7:1 overall shrinkage ratio) Based on the labor cost per hr	119 women at $0.60 per hr 32 men at $0.75 per hr 1 Foreman 1 Female Supervisor		$71.40 24.00 1.50 1.00
			$97.90
	Labor Cost per wet Pound (8,330 lbs)		1.17 cents
	Labor Cost per dry Pound (1,190 lbs)		8.2 cents
Steam Generating: Approx. Boiler horsepower needed: (2 bhp per ton per day) for blancher only	200 bhp		
Approx. cost of boiler if operated at rated capacity			$10,000

unless hand labor is to be used. In small plants, therefore, it is necessary to install machinery the capacity of which is out of proportion to the needs, and which cannot be put to full use. As an example, the same preparation machinery is adequate for a plant of 10 tons daily capacity as for a plant of 5 tons. This is apparent when it is known that the tonnage handled is directly proportional to the length of the operating day. Plants of 5 ton capacity per 24 hrs usually operate on a batch basis, and cabinet dryers would be used. In such cases, preparation lines will operate only 12 hrs out of the 24.

There should always be a proper balance between the preparation line and the dehydrater. It is a good plan to have the equipment between the trimming belt and the dehydrater sufficiently large to take care of any increase in the output of the trimming belt. The dehydrater itself should have enough capacity to handle the output of the preparation line. In some instances, if the dehydrater has sufficient reserve heat capacity, a sudden increase of raw material from the preparation line may be handled by decreasing the amount of air recirculated. As previously pointed out, this will increase fuel costs, but this increase will usually be offset by the increased capacity of the plant in such cases of emergency. The capacity of the dehydrater cannot be increased by increasing the tray loadings. This is a frequent mistake.

In Table 53 are given detailed data for equipment costs, amount of labor and labor costs for a plant handling 100 tons of white potatoes per 24 hours. It is again pointed out that these data should not be taken as exact, and they may vary from plant to plant; and they will vary according to the commodity being handled.

Included in the equipment costs are installation expenses plus costs for such accessory items as valves, piping, wiring, trucks, boxes, tools, scales, and other such items, plus some allowance for improvised items. It is estimated that these will make a total of about 50 per cent to be added to the purchase price to cover installation and all accessory items.

Labor Required. This item will vary with the product being processed as well as with the capacity of the plant. Table 54 gives an approximation of the number of employees needed in plants of different capacities and dehydrating different vegetables. The number of employees required cannot be fixed. Increased use of

Table 54. Approximate Number of Employees for Dehydrating Plants Processing Different Amounts of Various Vegetables. (Unprepared Basis)

(*Dehydration Committee, Bur. Agr. Chem. & Eng.*)

Operation	Beets	Cabbage	Carrots	Onions	Potatoes, white	Potatoes, sweet	Ruta-bagas
	Capacity: 400 lbs. per hr. (5 tons per day)						
Trucking and Washing	1M	1M	1M	1M	1M	1M	1M
Blanching	1M						
Topping, sorting, trimming	3F	1F	3F	2F	5F	3F	3F
Slicing, washing	1M	1M	1M		1M	1M	1M
Tray loading	1M	1M	1M	1M	1M	1M	1M
Scraping trays	1F	1F	1F	1F	1F	1F	1F
Packing and preparing for shipment	1M	1M	1M	1M	1M	1M	1M
General	2M	2M	2M	2M	2M	2M	2M
Total	7M 4F	6M 2F	6M 4F	5M 3F	6M 6F	6M 4F	6M 4F
	Capacity: 830 lbs per hr (10 tons per day)						
Feeding to prep. line	1M	1M	1M	1M	1M	1M	1M
Topping, trimming, or slicing	5F 1M	2F 1M	5F 1M	4F	10F	6F	5F 1M
Blanching, peeling or sizing	1M	1F	1F		1F	1F	1F
Tray loading	2M	2M	2M	2M	2M	2M	2M
Drying, moving cars	1M	1M	1M	1M	1M	1M	1M
Scraping trays	2M	2M	2M	2M	2M	2M	2M
Packing and preparing for shipment	2M	1F 2M	2M	2M	1F 2M	1F 2M	1F 2M
General	3M	3M	3M	2M	3M	3M	3M
Total	13M 5F	12M 4F	12M 5F	10M 4F	11M 12F	11M 8F	12M 7F
	Capacity: 1670 lbs per hr (20 tons per day)						
Feeding to prep. line	1M	1M	1M	1M	1M	1M	1M
Topping, trimming, or slicing	10F	1M 3F	10F	8F	20F	12F	10F
Blanching, peeling or sizing	2M	1F	1F		1F 1M	1F	1F
Tray loading	2F 2M	2F 2M	2M 2F	2M 2F	2M 2F	2M 2F	2M 2F
Drying, moving cars	1M	1M	1M	1M	1M	1M	1M
Scraping trays	4M	4M	4M	4M	4M	4M	4M
Packing, preparing for shipment	1F 1M	1F 1M	1F 1M	1F 1M	1F 2M	1F 2M	1F 2M
General	4M	4M	4M	3M	4M	4M	4M
Total	15M 13F	14M 7F	13M 14F	12M 11F	15M 24F	14M 16F	14M 14F
	Capacity: 3330 lbs per hr (40 tons per day)						
Feeding to prep. line	2M	2M	2M	2M	2M	2M	2M
Topping, trimming, or slicing	18F	6F 2M	20F	16F	40F	24F	18F
Blanching, peeling or sizing	3F	2F	2F		2F 1M	2F 1M	2F
Tray loading	2F 3M	2F 3M	2F 3M	2F 3M	2F 3M	2F 3M	2F 3M

Table 54. (*Continued*)

Capacity: 3330 lbs per hr (40 tons per day)

Operation	Beets	Cabbage	Carrots	Onions	Potatoes white	Potatoes sweet	Ruta-bagas
Drying, moving cars	2M	2M	2M	2M	2M	2M	2M
Scraping trays	4M	4M	4M	4M	4M	4M	4M
Packing, preparing for	5F	6F	5F	5F	6F	6F	6F
shipment	2M	2M	2M	2M	2M	2M	2M
General	6M	6M	6M	5M	6M	6M	6M
	19M	21M	19M	18M	20M	20M	19M
Total	28F	16F	29F	23F	50F	34F	28F

Capacity: 8330 lbs per hr (100 tons per day)

Operation	Beets	Cabbage	Carrots	Onions	Potatoes white	Potatoes sweet	Ruta-bagas
Feeding to prep. line	3M	3M	3M	3M	3M	3M	3M
Topping, trimming, or	46F	14F	50F	40F	100F	60F	46F
slicing		2M			1M	1M	
Blanching, peeling or sizing	4M	2F	2F		2F	2F	2F
Tray loading	4F	4F	4F	4F	4F	4F	4F
	4M	4M	4M	4M	4M	4M	4M
Drying, moving cars	3M	3M	3M	3M	3M	3M	3M
Scraping trays	7M	8M	7M	8M	7M	7M	7M
Packing, preparing	12F	13F	12F	12F	13F	13F	13F
for shipment	3M	4M	3M	3M	5M	5M	5M
General	10M	9M	10M	8M	10M	10M	10M
	34M	33M	30M	29M	33M	33M	32M
Total	62F	33F	68F	56F	119F	79F	65F

automatic machinery will decrease the need for employees to handle the material.

Drying of Fruits

Mrak and Long [1] have tabulated data showing the cost of sun-drying apricots, peaches and prunes from studies made by Burlingame, Hilliard, Bryant and Shultes of the University of Cali-

Table 55. Approximate Employees per Ton of Fresh Unprepared Vegetables Handled per 24 Hours in Dehydration Plants of Different Capacities

Plant Capacity	Beets	Cabbage	Carrots	Onions	Potatoes, white	Potatoes, sweet	Ruta-bagas
	Employees per ton of fresh unprepared vegetable						
400 lbs per hr (5 tons per day)	2.2	1.6	2.0	1.6	2.4	2.0	2.0
830 lbs per hr (10 tons per day)	1.7	1.5	1.6	1.3	2.2	1.9	1.8
1,670 lbs per hr (20 tons per day)	1.4	1.0	1.3	1.1	1.9	1.5	1.4
3,330 lbs per hr (40 tons per day)	1.2	0.9	1.2	1.0	1.7	1.3	1.2
8,330 lbs per hr (100 tons per day)	1.0	0.8	1.0	0.9	1.5	1.1	1.0

[1] Mrak, E. M., and Long, J. D., "Methods and Equipment for Sun-Drying of Fruits," *Univ. Calif. Agr. Exp. Sta. Circ.* 350 (1941).

Table 56. Apricot and Peach Sun-Drying Costs per Ton, Based on the Weight of the Fresh Fruit. Data for Stanislaus County, California
(*Mrak and Long*)

Item	Apricots		Freestone Peaches		Clingstone Peaches	
	1939	1940	1939	1940	1939	1940
Drying ratio	6.33:1	5.20:1	6.64:1	7.11:1	6.71:1	7.25:1
Cost per ton for drying, based on weight of fresh fruit						
Labor*	$ 8.65	$ 6.36	$4.20	$4.59	$6.83	$6.60
Material	0.32	0.61	0.27	0.24	0.20	0.18
Cash overhead	0.83	0.84	0.41	0.47	0.65	0.67
Depreciation	0.70	1.76	0.77	1.10	0.58	0.67
Interest on investment, 5%	0.35	0.60	0.38	0.54	0.31	0.38
Total	$10.85	$10.17	$6.03	$6.94	$8.57	$8.50

*Includes miscellaneous, etc.

Table 57. Cost per Dried Ton for Sun-Drying Prunes in Colusa County, Calif.
(*Mrak and Long*)

Year	1931	1938
Labor	$ 7.21	$ 7.60
Material	1.05	.50
Cash Overhead	0.78	0.52
Interest and Depreciation	4.30	4.41
Total	$13.34	$12.76

Table 58. Comparative Costs of Dehydrating Fruits, Based on Fresh Fruit
(*After Cruess*)

Type of Dehydrater	Capacity, fresh fruit per 24 hrs (tons)	Total first cost of plant	Fuel efficiency (%)	Labor	Fuel	Power and light	Total operating charge	Fixed charges*	Total cost
Air-blast tunnel, direct heat				$3.10	$0.94	$0.48	$4.61	$2.07	$6.68
Air-blast tunnel indirect heat	6.0	$ 4,000	38–58	4.16	2.05	0.45	6.66	2.32	8.98
Air-blast cabinet	12.0	15,000	30	4.80	1.63	0.55	6.98	4.34	11.34
Stack-type gravity air flow	9.0	25,000	24	9.75	3.26	0.20	13.21	9.68	22.89

*Interest, Depreciation, Insurance and Taxes.

fornia Agriculture Extension Service. A condensation of these data is given in Tables 56 and 57.

In Oregon, prunes are dehydrated, since the climate does not favor sun-drying. In California, most prunes are sun-dried, but

drying may be completed in a dehydrater if the weather becomes unfavorable during the drying period. Grapes may also be dehydrated, but peaches and apricots are most always sun-dried.

Table 58 gives data of costs of dehydrating such fruits as prunes and grapes as quoted by Cruess.[2] Fuel costs are based on 6 cents per gal for oil; power, 2½ cents per kilowatt hour, and labor at 50 cents an hour.

Christie[3] found that the average cost of dehydrating prunes was slightly greater per green ton than sun-drying. Thus:

Item	Av. for dehydration	Av. for sun-drying
Labor	$2.67	$3.68
Fuel	.87	.18
Power and light	.79	.04
Lye	.08	.09
Total	$4.41	$3.99

Cost of Drying Eggs

The following items should be considered factors in the cost of drying eggs:

(1) Delivered price of shell eggs.
(2) Candling.
(3) Breaking.
(4) Separating albumen from yolks.
(5) Drying.
(6) Packing and shipping.

All these factors are subject to variables, such as purchasing power, efficiency of the labor employed, efficiency and skill in operating the different machines and general plant lay-out.

Delivered Price of Shell Eggs. This will vary widely from season to season and from year to year, according to economic conditions and the quality of the eggs. In times of high purchasing power, the price of eggs will be so high that the egg dehydrator cannot operate at a profit. Such conditions may be said to exist during the present national emergency. Under present conditions, egg plants can operate at a profit, but only because the Government is purchasing practically the entire dehydrator's output at a price that assures him a reasonable profit.

[2] Cruess, W. V., "Commercial Fruit and Vegetable Products," 2nd Ed., McGraw-Hill Book Co., New York, 1938.

[3] Christie, A. W., "Successful Dehydration," *Pacific Rural Press*, p. 589 (Nov. 25, 1922).

Candling. This cost will vary according to the quality of the eggs being candled, the care in candling and the season of the year. In general, the cost will range from 8 to 15 cents a case. The former figure would be attained only when candling was not carried out with too much care.

Breaking. Termohlen, Warren and Warren[4] assume a cost of 50 cents a case to be representative. This figure will include all supplies, labor, rent, power and equipment.

Separating Albumen from Yolks. If albumen and yolks are not separated, about 50 per cent more eggs can be handled than when they are. It therefore costs more to make this separation, and this additional cost is estimated to be about 10 cents per case. In other words, when albumen and yolks are separated, breaking costs per case will be about 60 cents instead of 50 cents.

Drying Costs. Such costs will depend in a large measure upon the efficiency of the drying equipment and the skill exercised in operating it. As in the case of drying vegetables, improvement in equipment design will also affect the drying of eggs. In general, however, drying costs will average about 3.41 cents per pound for whole egg, 8.23 cents per pound for albumen and 2.87 cents per pound for yolks.[4]

Packing and Shipping. In bulk, dried eggs are packed in 200-lb barrels of soft wood (fir, elm, poplar or soft maple) with a double liner of waxed parchment. The outer liner is waxed to 45 lbs, the inner one to 15 lbs. For shipment to the British Isles, whole dried eggs are packed in 5-ounce individual cartons with a liner of "Thermophane" (Cellophane laminated to sulfite paper), or a similar material. These packages are in turn packed 24 to 48 to a wooden carton. Termohlen, Warren and Warren[4] give container cost for whole dried eggs (in barrels) as 0.51 cents per pound; for albumen, 0.53 cents per pound; and for yolk, 0.58 cents per pound.

Transportation costs to the seaboard (New York City) will amount to about 1.35 cents a pound.

Table 59 gives the estimated drying costs of whole eggs at various price levels of shell eggs.

In estimating costs for drying albumen and yolk, the value of the remaining part not dried must be considered. For example, if

[4] Termohlen, W. D., Warren, E. L., and Warren, C. C., "The Egg-Drying Industry in the United States," *U. S. Dept. Agr., Agr. Marketing Admin.* PSM-1 (1938).

albumen is dried the cost of the finished product will depend upon the price obtained for the liquid yolk. At the present time, very little albumen and yolk are being dried, production being concentrated on dry whole egg.

Table 59. Cost of Drying Whole Egg at Various Levels of Shell Egg Prices. (*After Termohlen, Warren and Warren, with additions*)

Cost of shell eggs delivered at plant (1) (cents per dozen)	Shell egg cost plus 2 cents candling and breaking costs (2) (cents per dozen)	Cost of liquid whole eggs (3) (cents per lb)	Liquid cost converted to dry form (4) (cents per lb)	Drying cost including freight and containers (5) (cents per lb)	Total cost (6) (cents per lb)
10	12	10.285	36.7174	5.27	41.9874
11	13	11.142	39.7769	5.27	45.0469
12	14	12.000	42.8400	5.27	48.1100
13	15	12.857	45.8994	5.27	51.1694
14	16	13.714	48.9590	5.27	54.2290
15	17	14.571	52.0184	5.27	57.2884
16	18	15.428	55.0780	5.27	60.3480
17	19	16.285	58.1374	5.27	63.4074
18	20	17.142	61.1969	5.27	66.4669
19	21	18.000	64.2600	5.27	69.5300
20	22	18.857	67.3195	5.27	72.5895
21	23	19.714	70.3789	5.27	75.6489
22	24	20.570	73.4349	5.27	78.7049
23	25	21.427	76.4944	5.27	81.7644
24	26	22.285	79.5575	5.27	84.8275
25	27	23.142	82.6069	5.27	87.8769
26	28	23.999	85.6764	5.27	90.9464
27	29	24.856	88.7359	5.27	94.0056
28	30	25.713	91.7954	5.27	97.0654
29	31	26.570	94.8549	5.27	100.1249
30	32	27.427	97.9144	5.27	103.1844
31	33	28.284	100.9730	5.27	106.2439
32	34	29.142	104.0369	5.27	109.3069
33	35	30.000	107.1000	5.27	112.3700
34	36	30.856	110.1559	5.27	115.4259
35	37	32.484	115.9679	5.27	121.2379

(1) Assumed level of price of delivered eggs.
(2) Column 1 plus 10 cents a case candling cost and 50 cents breaking costs.
(3) Column 2 divided by 1.1667, the average yield in liquid whole eggs from 1 dozen shell eggs.
(4) Column 3 multiplied by 3.57, the average number of pounds of liquid whole eggs required to make one pound of dried eggs.
(5) Drying costs per pound, made up of 3.41 cents drying cost, 0.51 cents for containers, and 1.35 cents for transportation to New York City.
(6) Total dried-egg cost for varying values of shell eggs.

Cost of Drying Milk

Holm [5] points out that the cost of drying milk will vary with the efficiency of the process used, the cost of fuel and various local conditions. In general, a skim-milk plant handling less than 30,000

[5] Holm, G. E., "Dried Milks," *U. S. Dept. Agr., Bur. Dairy Ind.* BDIM-812 (1942).

pounds of skim milk per day cannot be operated efficiently. Table 60 gives rough estimates for drying whole milk at different price levels for whole fluid milk.

Table 60. Estimated Approximate Cost of Drying Whole Milk at Different Price Levels for Fluid Whole Milk

Cost of fluid milk per 100 lbs. (cents)	Material cost per lb. dried milk* (cents)	Cost of drying, per lb. dry milk (cents)	Container cost per lb. dry milk (cents)	Total cost (cents)
50	4.00	2.00	0.53	6.53
75	6.00	2.00	0.53	8.53
100	8.00	2.00	0.53	10.53
125	10.00	2.00	0.53	12.53
150	12.00	2.00	0.53	14.53
175	14.00	2.00	0.53	16.53
200	16.00	2.00	0.53	18.53
225	18.00	2.00	0.53	20.53
250	20.00	2.00	0.53	22.53
275	22.00	2.00	0.53	24.53
300	24.00	2.00	0.53	26.53

*Based on a yield of 12.5 lbs of whole dry milk from 100 lbs of fluid whole milk.

Suggested Readings

"Estimates of Equipment Costs and Labor Requirements in Vegetable Dehydration. Plant Capacity: 400 Pounds per Hour (Unprepared Basis)," Dehydration Committee, *Bur. Agr. Chem & Eng., U. S. Dept. Agr.* (Aug. 1942).

"Estimates of Equipment Costs and Labor Requirements in Vegetable Dehydration. Plant Capacity: 830 Pounds per Hour (Unprepared Basis)," *ibid.*, (Aug. 1942).

"Estimates of Equipment Costs and Labor Requirements in Vegetable Dehydration. Plant Capacity: 1,670 Pounds per Hour (Unprepared Basis)," *ibid.*, (Aug. 1942).

"Estimates of Equipment Costs and Labor Requirements in Vegetable Dehydration. Plant Capacity: 3,330 Pounds per Hour (Unprepared Basis)," *ibid.*, (Aug. 1942).

"Estimates of Equipment Costs and Labor Requirements in Vegetable Dehydration. Plant Capacity: 8,330 Pounds per Hour. (Unprepared Basis)," *ibid.*, (Aug. 1942).

"Analyses of Processing Costs in Vegetable Dehydration, *ibid.*, (Oct. 1942).

Termohlen, W. D., Warren, E. L., and Warren, C. C., "The Egg-Drying Industry in the United States," *U. S. Dept. Agr., Agr. Adj. Admin.* PSM-1 (1938).

Cruess, W. V., "Commercial Fruit and Vegetable Products," 2nd Ed., McGraw-Hill Book Co., New York, 1938.

Mrak, E. M., and Long, J. D., "Methods and Equipment for Sun-drying of Fruits," *Univ. Calif. Agr. Exp. Sta. Circ.* 350 (1941).

Chapter 8

Nutritive Value of Dried and Dehydrated Foods

Dehydration and drying of foods brings about a concentration of the proteins, fats and carbohydrates, and a destruction of some of the vitamins. The extent of vitamin destruction will depend upon the care exercised in preparing the material before dehydration as well as on the dehydration process used.

At the present time, there seem to be two schools of thought relative to the degree of vitamin retention in dehydrated foods. One group believes that retention of vitamins is not necessarily important, but that the product obtained should be pleasing to the eye and be palatable. Any avitaminosis that might arise from prolonged consumption of dehydrated foods low in vitamins can be alleviated by taking vitamin preparations. The opponents of this hypothesis state that vitamin requirements can be neither adequately nor economically met by pure vitamin preparations because the body of man has not evolved so that he can function efficiently on synthetic tablets. Therefore, an adequate vitamin level should be obtained from the food consumed. It might also be pointed out that there is a shortage of pure vitamin preparations.

The vitamin potency of different commercially dehydrated foods is still unknown with any degree of certainty. Should the use of dehydrated foods become more widespread, this subject must surely be given serious consideration. Kohman [1] states that vitamin C suffers almost complete destruction in most dehydrated products, and that dehydrated vegetables retain their vitamin values but poorly. This is not necessarily true, as will be shown later. Tressler [2] has recently reviewed the literature dealing with the nutritive value of dried and dehydrated fruits and vegetables. From his survey, there is apparently a serious lack of adequate information.

[1] Kohman, E. F., "The Preservation of the Nutritive Value of Foods in Processing," *J. Am. Med. Assoc.*, 120, 831 (1942).

[2] Tressler, D. K., "Nutritive Value of Dried and Dehydrated Fruits and Vegetables," *New York State Agr. Exp. Sta. Techn. Bull.* 262 (1942).

Fruits

Fruits may be either sun-dried or dehydrated, or a combination of the two methods may be used. Most of the fruit thus prepared and found in commerce consist of apples, peaches, apricots, raisins, prunes, dates, figs, lemon juice and cranberries. The last two are not yet available to the civilian population of this country.

Morgan, Kimmel, Field and Nichols [3] found that sun-drying of Thompson Seedless grapes caused almost complete destruction of vitamin A, but that dehydration caused no appreciable loss. It was also found that sun-drying of grapes did not cause a loss in thiamin (B_1) potency, provided the fruit was not treated with sulfur dioxide before drying. Sulfuring destroyed much of the thiamin present. There was almost complete destruction of vitamin C in grapes during drying, regardless of whether or not the fruit was sulfured. Raisins were found to be low in riboflavin (B_2).

Figs. Morgan and her co-workers [4] found that dehydrated figs retained more vitamin A than did sun-dried figs. In some varieties of figs, vitamin A was better retained by sulfuring the fruit. However, sulfuring destroyed a large proportion of thiamin, but this loss was of less magnitude when the figs were dried without sulfuring. There was complete destruction of vitamin C in the figs when they were either sun-dried or dehydrated. Drying did not seem to affect the riboflavin content.

Apricots. Morgan, Field and Nichols [5] showed that when apricots were sun-dried without sulfuring there was a loss of from 76 to 82 per cent in their vitamin A potency, while the loss of A during the drying of sulfured fruit amounted to from 59 to 74 per cent. Unsulfured dried apricots were devoid of antiscorbutic properties. However, sulfured apricots, when either sun-dried or dehydrated, retained their vitamin C potency; retention was greater in the case of dehydrated than of sun-dried fruit.[6] For good retention of vitamin C, the fruit must contain from 450 to 500 ppm of sulfur dioxide.

[3] Morgan, A. F., Kimmel, L., Field, A., and Nichols, P. F., "The Vitamin Content of Sultanina (Thompson Seedless) Grapes and Raisins," *J. Nutrition,* 9, 369 (1935).

[4] Morgan, *et al.,* "The Vitamin Content of Figs," *ibid.,* 9, 383 (1935).

[5] Morgan, A. F., Field, A., and Nichols, P. F., "The Effect of Cooking on the Vitamin A and C Content of Fresh and Dried Apricots," *J. Agr. Res.,* 46, 841 (1933).

[6] Morgan, A. F., Field, A. and Nichols, P. F., "Effect of Drying and Sulfuring on Vitamin C Content of Prunes and Apricots," *ibid.,* 42, 35 (1931).

Peaches. Although sulfuring appears to retain vitamin A during the drying of apricots, Morgan and Field,[7] and Morgan [8] report but little loss of carotene (provitamin A) from unsulfured dried peaches, and a satisfactory retention of vitamin C in sulfured peaches.[7]

Prunes. Sulfuring will cause almost a complete loss of thiamin (B_1) in most cases, but lye-dipping appears to have no effect on this vitamin. Prunes retain their vitamin C only when subjected to the regular commercial practice of lye-dipping before sulfuring.[6]

Table 61. Vitamin Content of Some Dried Fruits
(*Data from Booher, Hartzler and Hewston, unless otherwise noted*)

Fruit	Vitamin A (I.U.)	Thiamin (B_1) (microgrms)	Riboflavin (B_2) (microgrms)	Ascorbic Acid (C) (milligrms)
		(expressed as per 100 grams)		
Apricots		171	57[c]	
Apricots, sulfured	5,800			10[c]
Banana powder (ripe)				
spray-dried				5.1
drum-dried				6.3
Cranberries	200[a]	0[a]		
Figs	59[c]–115	108[c]–300	100[c]	
Guavas				2000–3000[b]
Dates	41–350			
Prunes	1,400–3,400	225[c]	1,800[c]	
Raisins	95[c]	87–225	125[c]	
Peaches	3,400	36[c]	285[c]	31[c]

a Isham and Fellers, "Effect of Manufacturing Processes on the Vitamins of Cranberries," *Mass. Agr. Exp. Sta. Bull.* 296 (1933).

b Goldberg and Levy, "Vitamin C Content of Fresh, Canned and Dried Guava," *Nature* [London] 148, 286 (1941).

c Tressler, "Nutritive Value of Dried and Dehydrated Fruits and Vegetables," *New York State Agr. Exp. Sta. Techn. Bull.* 262 (1942).

Dates. Morgan [9] found that fumigation and pasteurization of dates had no effect on their vitamin A content. Smith and Meeker [10] reported, however, that when Deglet Noor dates were held for 72 hours at 100 to 105° F there was a loss in vitamin A potency. These same workers were unable to find appreciable amounts of either vitamin C or riboflavin (B_2) in three varieties of market dates they

[7] Morgan, A. F., and Field, A., "Vitamins in Dried Fruits. II. The Effect of Drying and Sulfuring upon Vitamin A of Fruits," *J. Biol. Chem.*, 88, 9 (1930).

[8] Morgan, A. F., "Nutritive Value of Dried Fruits," *Am. J. Public Health,* 25, 328 (1935).

[9] Morgan, A. F., "Vitamin Tests on California and Asiatic Dates," *J. Home Econ.*, 25, 603 (1933).

[10] Smith, M. C., and Meeker, L. A., "The Vitamin Content of Three Varieties of Dates," *Ariz. Agr. Exp. Sta. Techn. Bull.* 34 (1931).

examined. Morgan [9] noted that Deglet Noor dates had a slight antirachitic value. This is unusual, because vitamin D has never been observed in a plant.

Apples. Given, McClugage and van Horne [11] dehydrated apples at 95 to 104° F and at 131 to 140° F and found that the dehydrated product had no antiscorbutic properties. This is as would be expected when it is considered that even a fresh apple is low in vitamin C, and that these workers used apples that had been stored. The fruit was not sulfured before drying.

Table 61 gives the available data on the vitamin content of different dried fruits; and in Table 62 is given the approximate composition of dried fruits.

Table 62. Approximate Composition of Dried Fruits
(*Modified from Chatfield and Adams*)

Fruit	Water (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Sugars (%)	Undetermined (%)	Acid* (%)	Calories per lb
Apples	23.0	1.4	1.0	1.4	4.6	54.0	12.3	2.3	1,395
Apricots	24.0	5.2	0.4	3.5	3.2	46.0	12.7	5.0	1,325
Bananas	23.0	3.6	0.3	2.5	1.7	67.5†	....	1.4	1,360
Figs	24.0	4.0	1.2	2.4	5.8	55.0	7.0	0.6	1,365
Peaches	24.0	3.0	0.6	3.0	3.5	51.0	11.9	3.0	1,340
Pears	24.0	2.3	0.4	1.7	6.1	36.0	28.0	1.5	1,355
Prunes	24.0	2.3	0.6	2.1	1.6	41.5	26.2	1.7	1,355
Raisins	24.0	2.3	0.5	2.0	...	68.0	1.4	1.8	1,355

*As malic acid.
†Total carbohydrates, by difference.

VEGETABLES

Prescott and Sweet [12] apparently give the only published data on the approximate composition of dehydrated vegetables. These data are indicated in Table 63. As will be seen from this table, dehydration causes a concentration of minerals, fat, protein and carbohydrates. Whether these constituents, notably protein, are changed in biological value by the process of dehydration is unknown at present. Morgan [13] has shown that cereal proteins and

[11] Given, M. H., McClugage, H. B. and van Horne, E. G., "The Antiscorbutic Property of Fruits. II. An Experimental Study of Apples and Bananas," *Am. J. Dis. Children*, **23**, 210 (1922).

[12] Prescott, S. C., and Sweet, E. D., "Commercial Dehydration: A Factor in the Solution of the International Food Problem," *Ann. Am. Acad. Pol. Sci. Pub.* **1294** (1919).

[13] Morgan, A. F., "The Effect of Heat Upon the Biological Value of Cereal Proteins and Casein," *J. Biol. Chem.*, **90**, 771 (1931).

casein subjected to dry heat or toasting were not so well utilized for growth and did not allow such a favorable nitrogen balance as did raw cereals and casein. Considerable work has been done by other workers indicating that fish protein in fish meal dried at high temperatures has not the nutritive value of the same material dried at lower temperatures. Morgan and Kern[14] found that heat appeared to injure the protein of both beef and horse meat. In the light of the work outlined above, dehydration may affect the biological value of the protein in legumes and other vegetables containing significant proportions of protein. Kohman,[1] however, claims that the protein of all legumes "is improved nutritively by being subjected to heat." Finks and Johns[14a] found that cooked or auto-

Table 63. Approximate Composition of Dehydrated Vegetables
(*Prescott and Sweet*)

Vegetable	Water (%)	Ash (%)	Protein (%)	Crude Fiber (%)	Fat (%)	Carbohydrates (by diff) (%)	Calories per lb
Cabbage	4.63	6.07	15.06	8.07	1.09	65.08	1,536
Carrots	4.69	5.49	5.43	8.10	1.48	74.81	1,554
Onions	5.98	3.59	13.23	4.58	1.24	71.34	1,625
Parsnips	2.81	6.40	10.00	6.73	1.77	72.29	1,605
Potatoes, white	5.92	3.76	9.63	1.79	0.12	78.78	1,649
Tomatoes	4.59	7.12	15.71	7.90	2.53	62.15	1,555
Turnips	6.49	7.53	12.84	8.67	0.50	63.97	1,449

claved meal from Chinese and Georgia Velvet beans, supplemented with either cystine or casein, resulted in nutritional failure in laboratory animals. This may have been caused by some associated toxic substance in the meal. On the other hand, it was found that the isolated proteins, obtained by heat coagulation, were adequate for normal growth in laboratory animals. Waterman and Jones,[14b] working with the proteins of these beans, conducted digestibility tests *in vitro*. Their results indicated that the dialyzed protein from the Chinese beans was partially indigestible, and the protein prepared by coagulation showed an increase in digestibility; cooking the dialyzed proteins from both beans made them as digestible as the coagulated proteins. In the case of the Navy bean, Water-

[14] Morgan, A. F., and Kern, G. E., "The Effect of Heat Upon the Biological Value of Meat Protein," *J. Nutr.*, 7, No. 4, 367 (1934).

[14a] Finks, A. J., and Johns, C. O., "The Nutritive Value of the Proteins from the Chinese and Georgia Velvet Beans," *Am. J. Physiol.*, 57, 61 (1921).

[14b] Waterman, H. C., and Jones, D. B., "The Relative Digestibility of Various Preparations of the Proteins from Chinese and Georgia Velvet Beans," *J. Biol. Chem.*, 47, 285 (1921).

man and Johns[14c] found that the protein (phaseolin) of this bean was rendered more easily digestible by cooking. Finks and Johns,[14d] in their researches on lima beans, showed that a diet of cooked lima-bean meal to which 0.3 per cent cystine had been added, together with other non-protein necessary dietary ingredients, furnished adequate protein for normal growth of albino rats. On the other hand, a similar diet with no added cystine merely maintained the weight of the animals.

Data concerning the vitamin content of dehydrated vegetables are more meager than for dehydrated fruits, and also less conclusive.

Vitamin A. This does not exist as such in vegetables, but is present in the form of α- and β-carotene and cryptoxanthin, which are capable of being converted into vitamin A by the normal human organism. One molecule of β-carotene will yield two molecules of vitamin A, while the other "provitamins" named each yield one molecule of vitamin A.

DeFelice and Fellers[15] found that spinach lost over 90 per cent of its carotene content during dehydration. On the other hand, Steenbock and Gross[16] report that dehydrated spinach and chard possessed a fair vitamin A potency. Fraps and Treichler[17] state that an 80 per cent loss in carotene occurs when carrots are vacuum-dried. These workers also found a 29 per cent loss of vitamin A in vacuum-dried sweet potatoes, and a 65 per cent loss in vacuum-dried spinach. Morgan and Francis[18] found that dehydrated pumpkin was a good source of vitamin A. Lease and Mitchell[19] succeeded in preparing a sweet-potato flour of high vitamin A potency, and from their data it appears that no loss of vitamin A resulted during dehydration. In many of the foregoing cases, where loss of vitamin

[14c] Waterman, H. C., and Johns, C. O., "The Effect of Cooking on the Digestibility of Phaseolin," *ibid.*, 46, 9, (1921).

[14d] Finks, A. J., and Johns, C. O., "The Nutritive Value of the Proteins of the Lima Bean, *Phaseolus Lunatus*," *Am. J. Physiol.*, **56**, 205 (1921).

[15] DeFelice, D., and Fellers, C. R., "Carotene Content of Fresh, Frozen and Dehydrated Spinach," *Proc. Amer. Soc. Hort. Sci.*, **35**, 728 (1937).

[16] Steenbock, H., and Gross, E. G., "Fat-Soluble Vitamins. IV. Fat Soluble Vitamin of Green Plant Tissues Together with Some Observations on their Water-Soluble Vitamin Content," *J. Biol. Chem.*, **41**, 149 (1920).

[17] Fraps, G. S., and Treichler, R., "Losses of Vitamin A in Drying Fresh Raw Carrots and Sweet Potatoes and Canned Spinach," *J. Agr. Res.*, **47**, 539 (1933).

[18] Morgan, A. F., and Francis, L. D., "Biological Food Tests. VII. Vitamin A and B Content of Fresh and Dehydrated Pumpkin," *Am. J. Physiol.*, **69**, 67 (1924).

[19] Lease, E. J., and Mitchell, J. H., "Biochemical and Nutritional Studies of Dehydrated Sweet Potatoes," *South Carolina Agr. Exp. Sta. Bull.* 329 (1940).

A has been reported during dehydration, the vegetable was not previously blanched. Wilson, Thomas and DeEds,[20] examining carrots that had been properly blanched and dehydrated in accordance with the best commercial practice, found a 6 per cent loss of vitamin A during the process. From the standpoint of dietetics, this loss is probably not significant. Incidentally, their work showed a very close correlation between the amount of carotene, as determined by chromatographic methods, and vitamin A determined by bioassays. MacKinney, Aranoff and Borstein [21] found about a 40 per cent loss in carotene in dehydrating unblanched carrots, while they obtained only a 4.5 per cent loss in dehydrating blanched carrots. After 4 months' storage, the unblanched had lost about 95 per cent of their carotene, while the blanched had lost about 69 per cent.

From unpublished data dealing with the fate of vitamin A during the dehydration of vegetables, it seems quite probable that its loss is not serious, provided the vegetable is properly blanched before dehydration.

Thiamin (vitamin B_1). Farrell and Fellers [22] report no significant loss (less than 10 per cent) in snap beans that had been blanched and then dehydrated in a tunnel dryer. Morgan and Francis [18], in their work on pumpkin flour, found that the product had suffered only a slight loss in "vitamin B." It should be pointed out, however, that these workers are apparently reporting the B complex, for thiamin was not known at the time their researches were undertaken. Later Morgan and Lackey [23] investigated the loss of thiamin in the canning and dehydration of spinach and found a 23 per cent loss in dehydrating, compared to a 74 per cent loss in canning. The high loss in canning is rather surprising, and may have been due to the poor quality of the particular lot of spinach examined, which may not have been representative of an

[20] Wilson, R. H., Thomas, J. O., and DeEds, F., "Vitamin A Value of Fresh and Dehydrated Carrots," *Fruit Prod. J.*, 22, No. 1, 15 (1942).

[21] MacKinney, G., Aranoff, S., and Borstein, B. T., "Some Assays of Provitamin A Carotenoids," *Ind. Eng. Chem., Anal. Ed.*, 14, 391 (1942).

[22] Farrell, K. T., and Fellers, C. R., "Vitamin Content of Green Snap Beans. Influence of Freezing, Canning and Dehydration on the Content of Thiamin, Riboflavin, and Ascorbic Acid," *Food Res.*, 7, 171 (1942).

[23] Morgan, A. F., and Lackey, D., "The Effect of Various Methods of Preservation upon the Vitamin B Content of Spinach," *Univ. Calif. Household Sci. Lab.* (Prelim. Mimeo. Rept.), 1934.

average pack of the commodity. Morgan and Lackey, however, do not make this explanation.

Shorten and Ray [24] in their experiments on sun-dried vegetables (carrots, brinjal, spinach, tomatoes and potatoes), which had been blanched before drying, found that all these possessed marked thiamin potency.

In general, it is believed that vegetables that have been properly blanched, and dehydrated with ordinary care will not show a great loss of thiamin. However, the loss will be greater than that of carotene in most cases.

Riboflavin (vitamin B_2). The literature contains little reliable information regarding the loss of riboflavin during the dehydration of vegetables. Farrell and Fellers,[22] however, found that snap beans lost little of their riboflavin potency during dehydration. Although riboflavin is resistant to heat, significant losses in this vitamin have been known to occur during dehydration, and in many instances such losses have been as great as those of vitamin C.

Ascorbic acid (vitamin C). This vitamin, being prone to rapid destruction, especially in an alkaline medium and in the presence of oxygen, is the most difficult of all the vitamins mentioned thus far to retain. Given and McClugage [25] found that the temperature of dehydration had an effect on vitamin C retention. However, their experiments were carried out with an unblanched product. Potatoes that were thoroughly steamed and then dehydrated did not retain significant amounts of vitamin C. Farrell and Fellers [22] found that vitamin C was almost totally destroyed during the dehydration of snap beans. On the other hand, Shorten and Ray [24] reported that blanched and sun-dried tomatoes, potatoes, and cabbage retained considerable antiscorbutic potency, while sun-dried carrots, spinach, turnips and turnip tops had no antiscorbutic properties. Dutcher [26] pointed out that rapid drying in an inert atmosphere preserved vitamin C in spinach. Chace [27] reported better

[24] Shorten, J. A., and Ray, C. B., "The Antiscorbutic and Antiberiberi Properties of Certain Sun-Dried Vegetables," *Biochem, J.*, 15, 274 (1921).

[25] Given, M. H., and McClugage, H. B., "Antiscorbutic Property of Vegetables. II. An Experimental Study of Raw and Dried Potatoes," *J. Biol. Chem.*, 42, 491 (1920).

[26] Dutcher, R. A., "Factors Influence the Vitamin Content of Foods," *Penn. Agr. Exp. Sta. Techn. Bull.* 275 (1932).

[27] Chace, E. M., "The Present Status of Food Dehydration in the United States," *Proc. Inst. Food Techn.*, p. 70, (1942).

vitamin-C retention in rapid drying at high temperatures than in slower drying at lower temperatures. Javillier[28] indicated that the ascorbic acid content of commercially dehydrated potatoes was about 20 mg per 100 g. This figure is close to that of Chace[27], who reports 26 mg per 100 g in dehydrated potatoes produced in pilot plant operations. Dunker and Fellers[29] dehydrated spinach on a laboratory scale and found a total loss of ascorbic acid. Unfortunately, the authors do not describe their method of dehydration.

Table 64. Vitamin Content of Freshly Dehydrated Vegetables
(*After Dehydration Committee*)

Commodity	Carotene (mg 100 g)	Thiamin (microgrms per 100 g)	Riboflavin (micrograms per 100 g)	Ascorbic acid (mg per 100 g)
Beets	..	40	350	25
Cabbage (Savoy)	3	630	830	354
Carrots	90	300	300	27
Chard	4	550	1120	125
Kale	16	500	900	300
Mustard greens	50	...	....	400
Onions	..	...	....	58
Potatoes, white	..	420	250	25
Potatoes, sweet	17	200	320	41
Rutabagas	..	...	....	86
Spinach	40	750	1150	150

Table 64, taken from Dehydration Committee data, shows the vitamin content of freshly dehydrated vegetables prepared from fresh vegetables that had been grown in California. The material was dehydrated in a tunnel dryer on a pilot plant scale. The data do not necessarily represent values of dehydrated vegetables from material grown in other sections of the country. For this reason, as well as the fact that vitamin potency decreases during storage, the dehydrator should make no claim as to the vitamin content of his product.

Dry Milk

The vitamin potency of dry milk will depend not only upon the method of drying, but also upon the vitamin content of the fluid milk used. The vitamin content of fluid milk is subject to wide variations, depending upon the source of supply, season of the year, feed, breed of cow, and period of lactation. There is con-

[28] Javillier, M. A., "A Preliminary Consideration of the Retention of Vitamin C Content of Dried Potatoes," *Comp. rend. acad. agr. France*, 25, 1093 (1939).

[29] Dunker, C. F., and Fellers, C. R., "Vitamin C Content of Spinach," *Proc. Am. Soc. Hort. Sci.*, 36, 500 (1938).

siderable experimental work reported in the literature that apparently has failed to take these variables into account; this has resulted in conflicting evidence in many cases. From data that appear to be dependable, the following brief summary is given regarding the vitamin potency of dry whole milk.

Vitamin A seems to survive most drum-drying and spray-drying processes, and freshly dried milk made by either process retains the vitamin-A potency of the original fluid milk. Booher and Marsh [30] report 1,600 I. U. of vitamin A in a commercial sample of dry milk. Hunziker [31] states that dry milk powders may be expected to retain their vitamin A for a prolonged period if stored in air-tight, moisture-proof containers, preferably under vacuum or packed in nitrogen.

Thiamin (vitamin B_1). There is some loss of thiamin brought about by drying milk by both the spray and drum methods. This vitamin is retained fairly well during storage, however, if the milk is packed in proper containers. Booher and Hartzler [32] report 315 micrograms per 100 grams of thiamin in a commercial sample of dry milk.

Riboflavin (vitamin B_2). Hunziker [31] reports that riboflavin may be expected to be present in milk prepared by both drum- and spray-drying in amounts equivalent to those in the original fluid milk. Henry, Houston and Kon,[33] working in England, found from 930 to 1020 micrograms of riboflavin per 100 grams of spray-dried milk. Sullivan and Norris [34] reported from 2,980 to 2,140 micrograms of riboflavin in 100 grams of commercially dried milk found on the American market.

Ascorbic acid (vitamin C). As previously mentioned, this vitamin is particularly sensitive to oxidation, especially in the presence

[30] Booher, L. E., and Marsh, R. L., "The Vitamin A Value of 128 Foods as Determined by the Rat Growth Method," *U. S. Dept. Agr. Techn. Bull.* 802 (1941).

[31] Hunziker, O. F., "Condensed Milk and Milk Powder," 5th Ed., Published by the author, La Grange, Ill., 1935.

[32] Booher, L. E., and Hartzler, E. R., "The Vitamin B_1 Content of Foods in Terms of Crystalline Thiamin," *U. S. Dept. Agr. Techn. Bull.* 707 (1939).

[33] Henry, K. M., Houston, J., and Kon, S. K., "The Estimation of Riboflavin. Part 2. The Estimation of Riboflavin in Milk; Comparison of Fluorometric and Biochemical Tests," *Biochem. J.*, **34**, 607 (1940).

[34] Sullivan, R. A., and Norris, L. C., "Determining Riboflavin in Dried Milk Products," *Ind. Eng. Chem., Anal. Ed.*, **11**, 535 (1939).

of heat. Hess and Weinstock[35] have pointed out that copper, even in minute amounts, greatly hastens the destruction of vitamin C. This action, together with that of heat and oxidation, renders all dry milks deficient in antiscorbutic properties. Woessner, Elvehjem and Schuette,[36] however, found 9.71 mg of ascorbic acid per 100 g of dry whole milk prepared by the drum process, and 6.9 mg per 100 g of spray-dried milk. When the drum-dried milk was reconstituted to 12.5 per cent total solids, the product had 1.4 mg of vitamin C per 100 cc, not much less than found in whole raw milk.

Vitamin D. Dry milk, prepared by either drum- or spray-drying, does not contain sufficient vitamin D to prevent rickets. This may be overcome by adding Viosterol, cod-liver or halibut-liver oil to the fluid milk, or by irradiation with ultraviolet rays of the proper wave length.[37]

Other Vitamins. Holm [38] states that fluid milk contains pyridoxine (vitamin B_6) and niacin (vitamin P-P), and that these are not materially affected by the process of drying.

Digestibility of Dry Milk. The digestibility of dry milk has been found to be high and it is therefore considered a satisfactory substitute for fluid whole milk. According to Holm [38], drying milk by processes that use low temperatures does not materially change the type of acid curd that the reconstituted milk will form. When the milk is dried at high temperatures, however, a rather insoluble product is formed, and when this type of milk is reconstituted, the curd formed is flocculent. For infants who cannot tolerate other milks, such a product is sometimes of special value.

Miyawaki, Kanazawa and Kanda [39] studied the protein digestibility of dry milks. Drying increased the protein digestibility, and

[35] Hess, A. F., and Weinstock, M., "The Catalytic Action of Minute Amounts of Copper in the Determination of Antiscorbutic Vitamin in Milk," *J. Am. Med. Assoc.*, 82, (March 22, 1924).

[36] Woessner, W. W., Elvehjem, C. A., and Schuette, H., "The Determination of Ascorbic Acid in Evaporated Milk, Powdered Milk and Powdered Milk Products," *J. Nutr.*, 20, 327 (1940).

[37] DeSanctis, A. G., Ashton, L. O., and Stringfield, O. L., "A Study of the Antirachitic Value of Irradiated Powdered Whole Milk," *Arch. Pediat.*, 46, 297 (1929).

[38] Holm, G. E., "Dried Milks," *U. S. Dept. Agr., Bur. Dairy Ind.* BDIM-812 (Rev. March, 1942).

[39] Miyawaki, A., Kanazawa, K., and Kanda, S., "The Digestibility of Protein of Dried Mi'k Manufactured by Different Processes," *J. Dairy Sci.*, 15, 62 (1932).

the protein of spray-dried milk was more digestible than that of drum-dried, as determined *in vitro*. However, *in vivo* experiments showed no difference in digestibility between the two products.

Dehydrated Meat and Eggs

Published data on the nutritive value of dehydrated meat and eggs are meager. Bate-Smith[39a] found that the protein value of meat dehydrated below 176° F was the same as that of cooked meat. There is a loss of thiamin during dehydration, the loss increasing with increase of drying temperature. No loss of niacin or riboflavin occurs if the meat is dehydrated at 158° F. In the case of eggs, Bate-Smith found that there was little loss of either vitamin A or thiamin by spray drying. However, if the eggs were tray-dried, there was a loss of A and a 50 per cent reduction in thiamin potency. In spray drying there was a 30 per cent loss in thiamin. No reduction in vitamin potency resulted when the eggs were dried under high vacuum at a low temperature. Hauge and Zscheile[39b] reported that no loss of vitamin A took place during the spray drying of eggs.

Dried Blood and Beef Serum

Practically all the data relative to the nutritive value of blood has come to us from Germany. Several years before the First World War, research workers in Germany were investigating this field, and when the war broke out several blood preparations were on the market. Among the most widespread of these were Hämalb, Bovisan, Prothämin, Sanol and Roborin. The nutritive value of many of these had been investigated 8 to 10 years before 1914.

Hämalb was a yellowish albumen preparation obtained from beef blood serum and was used as a substitute for eggs. It contained 7.7 per cent water, 77.4 per cent water-soluble albumen and 9.17 per cent ash. In a 12 per cent solution, it was used in baking and to prepare a paste for noodles, dumplings and pancakes, as well as for a binding medium for mincemeat.

Bovisan was prepared from blood dried in a current of warm (113° F) air; the dried mass was then powdered, giving a reddish-

[39a] Bate-Smith, "Dehydrated Meat and Eggs," *Chem. & Ind.*, 61, No. 32, 342 (1942).

[39b] Hauge, S. M., and Zscheile, F. P., "Effect of Dehydration on the Vitamin A Content of Eggs," *Science*, 96, 536 (1942).

brown product, insoluble in water. This product contained between 75 and 80 per cent protein. The material had poor keeping qualities and after a few months acquired an offensive odor and became unpalatable. It was used chiefly as an addition to bread, zwieback, cocoa and chocolate.

Prothämin was prepared by diluting blood with water, heating to 158° F, and then decolorizing with hydrogen peroxide. The coagulated mass was pressed, washed with warm water, then with alcohol and ether, dried and pulverized. On a commercial scale, it was found impossible to decolorize the material with hydrogen peroxide, and the product was sold as a chocolate-colored powder, odorless and tasteless and only slightly soluble in water. In feeding tests on dogs, it was found that 95 per cent of the nitrogen was absorbed, but there are no data showing its utilization by the human organism. Prothämin contained 8.5 per cent water, 90.2 per cent nitrogenous matter, 0.2 per cent fat, and 1.1 per cent ash.

Roborin, prepared by precipitating the albumen in fresh beef blood as calcium albuminate, was a black, granular, gritty powder, odorless and with an alkaline taste. It never found much favor because of the black color it imparted to the foods in which it was used.

Whole dried blood was also prepared by the Krause process in the same manner as spray-dried milk. Most of this material was made in Munich. The nutritive value of the preparation was determined on two experimenters, who consumed 43.3 grams of the dried blood per day along with butter and "Grünkern" baked into "Frikadellen," which they ate three times a day. It was found that from 20 to 28.5 per cent of the nitrogen of the blood again appeared in the feces. Other experimenters found that from 95 to 96 per cent of the nitrogenous matter of blood was absorbed, and was equal in this respect to meat. On the other hand, there is some evidence to indicate that blood is poorly utilized because its hemochromogen is split into hematin, which is absorbed only with difficulty. However, blood serum appears to be readily absorbed and is about equal to the albumen of meat. *In vitro* experiments * of the peptic and tryptic digest of coagulated beef serum and coagulated egg albumen showed that in a peptic digest from 38.5 to 43 per cent of serum albumen was digested, compared with from 25 to 36 per cent of

* Unpublished data by the author.

egg albumen. In the tryptic digest, 50 per cent of serum albumen was digested, compared with 25 per cent of egg albumen.

Experiments conducted in an industrial laboratory * indicated that beef serum was not adequate to support the growth of white rats. In other feeding tests,† newly weaned white rats failed to grow on a diet containing coagulated dried beef serum as the sole source of protein.

The chief objection to using blood in food is the poor keeping quality of blood, and the chance of bacterial contamination. In whole blood or in fresh serum, the organisms found in the slaughterhouse spread and grow rapidly. The decomposition of blood by these organisms brings about the formation of offensive tastes, and even toxic products. However, if the material is handled quickly and in a clean and sanitary manner, there is no reason why it cannot serve as a food of high protein content.

Suggested Readings

Tressler, D. K., "Nutritive Value of Dried and Dehydrated Fruits and Vegetables," *New York State Agr. Exp. Sta. Techn. Bull.* 262 (1942).

Hunziker, O. F., "Condensed Milk and Milk Powder," 5th Ed., Published by the Author, La Grange, Ill., 1935.

Booher, L. E., Hartzler, E. A., and Hewston, E. M., "A Compilation of the Vitamin Values of Foods in Relation to Processing and other Variants," *U. S. Dept. Agr. Circ.* 638 (1942).

von Loesecke, H. W., "Proteins from Beef Blood," Unpublished Thesis (1927).

Mitchell, J. H., and Lease, E. J., "Stability of Carotene in Dehydrated Sweetpotatoes," *South Carolina Agr. Exp. Sta. Bull.* 333 (1941).

Booher, L. E., Hartzler, E. R., and Hewston, E. M., "A Compilation of the Vitamin Values of Foods in Relation to Processing and other Variants," *U. S. Dept. Agr. Circ.* 638 (1942).

Prescott, S. C., and Sweet, L. D., "Commercial Dehydration: A Factor in the Solution of the International Food Problem," *The Annals of the Am. Acad. Polit. and Soc. Sci.*, Pub. No. 1294 (May, 1919).

Horsford, E. N., "The Army Ration," 2nd Ed., Van Nostrand, New York, 1864.

* Unpublished data

† Unpublished data by the author.

Chapter 9

Packaging and Storage

The packaging of dehydrated foods should be carried out in a cool, clean, dry, well ventilated room separate from other parts of the dehydrating plant. Doors and windows should be screened, and every effort made to exclude dust and insects. If the foods are not stored in metal containers, constant vigilance must be exercised against rodents, and control methods instituted as described in Chapter 6.

Dried and dehydrated foods should be stored in a dark, dry, cool place; the lower the temperature of storage, the longer the life of the product.

INSECT INFESTATION

Fumigation against insects will be of no value after the material is in the final container. In the case of vegetables, even if insect larvae are present, it is unlikely that they will hatch in the dried product because of the low moisture content. Insects will, however, infest dehydrated vegetables if the package is broken, allowing free entrance. Even a minute pin-hole in the package will attract insects and encourage entrance. If there is any reasonable doubt concerning insect infestation, the product and empty package should be heated to 135° F for 5 minutes * immediately before packaging.

Insect infestation of dried fruits is quite common and is controlled by fumigation as described in Chapter 2. It is important to have strict orchard and drying-yard sanitation; all dried fruits should be fumigated before they leave the drying yard.

Insects causing damage to cut fruits are as follows:

Indian-Meal Moth (*Plodia interpunctella* Hubn.) which has the following characteristics:

* This means that the temperature of the material and the package should be maintained at 135° F for a period of 5 min.

Larvae are yellowish-white, about 1 in long, and when fully grown are inclosed in a small white cocoon. Fruit or containers infested will be covered with a web rendering the product unsightly. The moth itself is about $\frac{1}{2}$ to $\frac{3}{4}$ in long, the anterior part of the wings being silvery and the posterior copper-colored or half bronze.

Raisin moth (*Ephestia figulilella* Greg.), which is found throughout the fruit-drying area in California, resembles the Indian-Meal moth in appearance. It usually does not breed in warehouses. The raisin moth is controlled by eliminating all waste fruits and pits about the drying yards, because these act as breeding places for the larvae. This is especially true where such fruit is in the shade; fruit exposed to the sun is not generally infested.

Dried-fruit beetle. (*Carpophilus hemipterus* Linn.) is not so troublesome during the drying of fruit, but is attracted by wet, fermenting fruit. The larvae of the insect are small and whitish-yellow and they reduce the fruit to a fine powder or "frass." No web is formed.

PACKAGING OF DRIED FRUIT

Apples are packed in 50-lb boxes. The side of the box intended for the top is packed first with carefully selected pieces neatly arranged on a lining of paraffined paper. The succeeding layers of fruit are not so carefully arranged, and when the desired weight of fruit has been placed in the box, the cover is nailed on. This side then becomes the bottom.

Apricots are first processed as previously described (p. 50) and then packed in 25- to 50-lb boxes. The fruit is pressed into the box so that the material is level with the top of the container.

Figs are packed as "bricks," "bulk," and "fancy packs." In brick packing, the fruit is slit from stem to the eye and then rolled and flattened in such a manner that the fig is spread wide, thus concealing the stem. The flattened fruit is carefully placed into forms, which are then filled and pressed. The bricks thus obtained are wrapped in waxed paper and a label attached in such a manner as to hold the ends of the wax paper in place.

Bulk-packed figs are those not suitable for bricks, and are packed in 25- and 50-lb wooden boxes for the baking trade.

Fancy packs are made from large fruit. The figs are manipulated with the hands until soft and pliable and then formed into the

shape desired. Circular boxes may be used for packing, the fruit being arranged in an attractive pattern by using black and white figs.

Pears are packed in 10-, 25- and 50-lb boxes for wholesale trade. If the fruit is too dry, it is processed before packing, in the same manner as apricots (p. 50).

Peaches are generally fumigated before packing and then processed in the same manner as apricots. They are packed in 25- and 50-lb wooden boxes.

Prunes are packed while still hot in standard 25- or 50-lb paper-lined wooden boxes. The loose fruit will more than fill the box and the prunes are therefore pressed flush with the top. As the fruit is still warm when packed, the boxes should be staggered when piled so that there is free circulation about the stacked fruit.

Prunes are also packed in 1-, 2-, 3-, 5- and 10-lb cartons for family use.

Raisins are packed in cartons holding from 12 to 15 ounces. Seeded Muscat raisins are packed while still hot direct from the seeder (p. 65). Thompson seedless are machine packed, but Muscats are packed by hand. The fruit is also packed into fiber boxes holding 25 lbs.

Table 65. Dimensions (inside) of California Dried Fruit Boxes (25-lb size)

Fruit	Size of box (in)	Cubical Contents (in)	Cubical Contents (ft)	Wt per cu foot (lbs)	Remarks
Apricots	$14\frac{1}{4} \times 9\frac{1}{8} \times 6\frac{3}{4}$	877.7	0.51	49.2	wooden box
Peaches	"	"	"	"	" "
Prunes	$14\frac{1}{2} \times 9\frac{1}{8} \times 5\frac{3}{4}$	747.7	0.43	57.8	" "
Raisins	$14\frac{1}{2} \times 10\frac{1}{2} \times 6\frac{5}{8}$	1008.7	0.58	42.8	fiber box
Other fruits	$14\frac{7}{16} \times 9\frac{7}{16} \times 5\frac{3}{4}$	783.3	0.45	55.1	wooden box

Packing of Dried Vegetables

Satisfactory packing of dehydrated vegetables is much more difficult than that of dried fruits. The high percentage of sugar and acid in the latter aids in their preservation, but vegetables are low in sugar and thus lack this protection. The ideal package for dehydrated vegetables is a metal container, and this does not necessarily have to be a tin container. However, the shortage of steel has rendered even this type of package nearly impossible to obtain, and intensive researches are being conducted to find a substitute for metal containers. It should be borne in mind that packages for

the armed forces will in many cases be thrown overboard and allowed to float to shore with the tide. The following points are considered of importance in the selection of a suitable packaging material:

(a) The package should be heat-sealed, or completely sealed in some other suitable manner. The weakest part of the package is the seal.

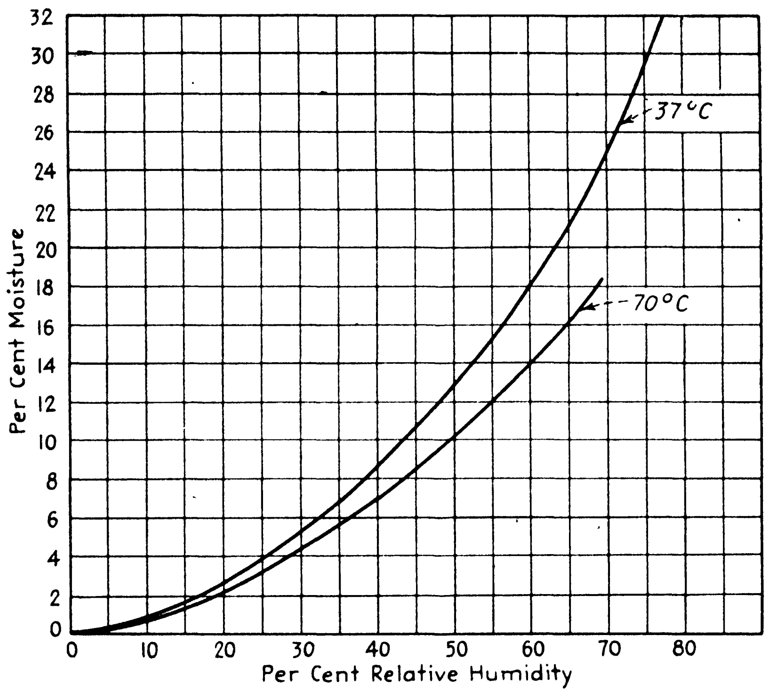


FIG. 48. Equilibrium-moisture curves for carrots. These are composite absorption and desorption curves. [From data of Makower and Dehority: *Ind. Eng. Chem.*, 35, 193 (1943).]

(b) The strength of the package liner should be sufficient to prevent perforation of the container or opening of the seam when the package is roughly handled.

(c) Transmission of water vapor into the package should not exceed 2 per cent of the bone-dry weight of the contents when stored for one year at 90° F and 90 per cent relative humidity, regardless of the package size.

(d) The sealed packaging material, backed by its container,

should remain intact after being subjected to a temperature of 130° F for 4 hrs.

(e) Packaging material should be such that satisfactory linings up to one cubic foot size of carton can be lined with a sealed envelope.

(f) The material should not crack at −15° F even when subjected to rough handling.

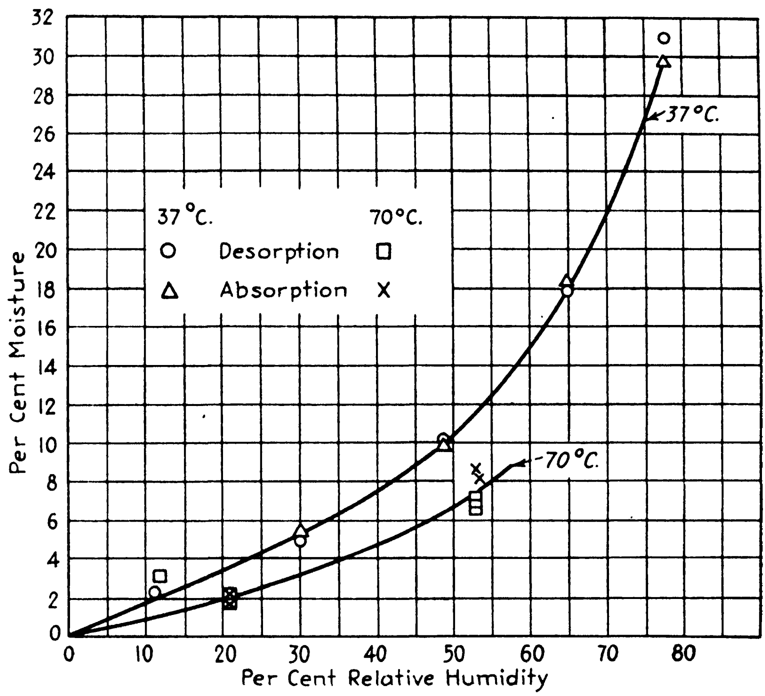


FIG. 49. Equilibrium-moisture curves for cabbage. [After Makower and Dehority: *Ind. Eng. Chem.*, 35, 193 (1943)].

(g) Packaging material should not impart a flavor to the product.

(h) Packages for certain dehydrated vegetables, such as cabbage, carrots and greens (spinach, kale, chard, etc.) should be capable of retaining carbon dioxide or nitrogen. In general, oxygen should not enter such a package at a rate greater than 1 per cent of the gaseous volume per month.

(i) Packages should be insect-proof.

(j) Packaging material should be readily available.

Up to the present time, no package, with the exception of the metal container, has been found to meet all these requirements. Pitman, Rabak and Yee[1] have investigated the moisture-vapor permeability of several packaging materials and have used Carson's formula[2] to express this permeability in a simple equation, which can be turned to practical use as explained later. This equation, as expressed by Pitman, Rabak and Yee, is as follows:

$$K = \frac{W - W_0}{A(VPD)_t} \qquad \text{(I)}$$

$$VPD = P_w \frac{(\%\text{RH})_s - (\%\text{RH})_c}{100} \qquad \text{(II)}$$

where K = water-vapor permeability (in grams/24 hrs/sq meter/millimeter of mercury difference of water vapor pressure).

W_0 = initial weight, in grams, of package contents.

W = final weight of package contents, in grams, after t days.

t = time of storage, in days.

A = effective area of the package lining (in sq. meters).

P_w = pressure of saturated water vapor at the temperature of storage.

VDP = vapor pressure difference between the outside and inside of the package.

$(\%\text{RH})_s$ = % relative humidity of air in the storage space.

$(\%\text{RH})_c$ = % relative humidity of air in the package itself.

The water-vapor resistance of the package would be the reciprocal of the water-vapor permeability, *i.e.*, $R = \frac{1}{K}$, where R = the water-vapor resistance.

As an example of the practical application of this formula, let it be supposed that potato cubes are to be packaged in a cubic foot container, and would be stored for 6 months under such climatic conditions that the average temperature will be 50° F and the

[1] Pitman, A. L., Rabak, W., and Yee, H., "Packaging Requirements for Dehydrated Vegetables," *Food Ind.*, **15**, No. 1, 49 (1943).

[2] Carson, F. T., "Permeability of Membranes of Water Vapor with Special Reference to Packaging Material," *National Bureau Standards Misc. Pub.* M127.

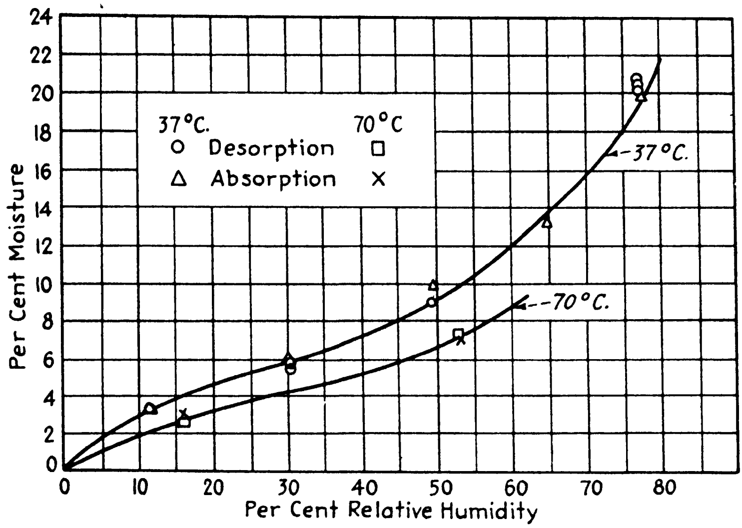


Fig. 50. Equilibrium-moisture curves for sweet potatoes. [From data of Makower and Dehority: *Ind. Eng. Chem.*, 35, 193 (1943)].

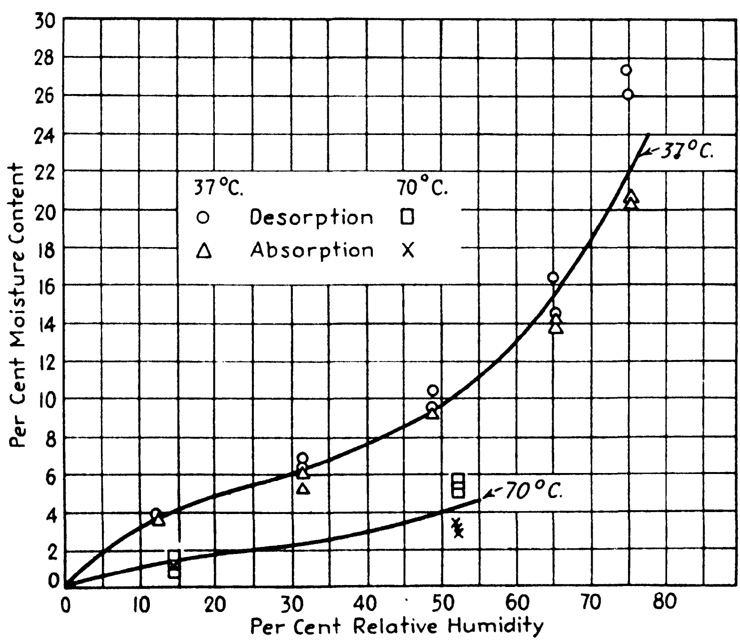


Fig. 51. Equilibrium-moisture curves for spinach. [After Makower and Dehority: *Ind. Eng. Chem.*, 35, 193 (1943).]

average relative humidity will be 70 per cent. From Table 30 it is found that one cubic foot of dehydrated potato cubes weighs about 24 lbs. Then $24 \times 2\% = 0.48$ lb, the gain in weight of the package. From this figure it is found that $W - W_0 = 0.48 \times 454 = 217$ grams. The area of the package lining, A, will be $6'' \times 12'' \times 12''$, or 864 sq in.* To change this to meters it is multiplied by 0.00065, which will give 0.56 sq meter. At 50° F, the temperature at which the package will be stored, the vapor pressure is 9.2 mm of mercury, and this

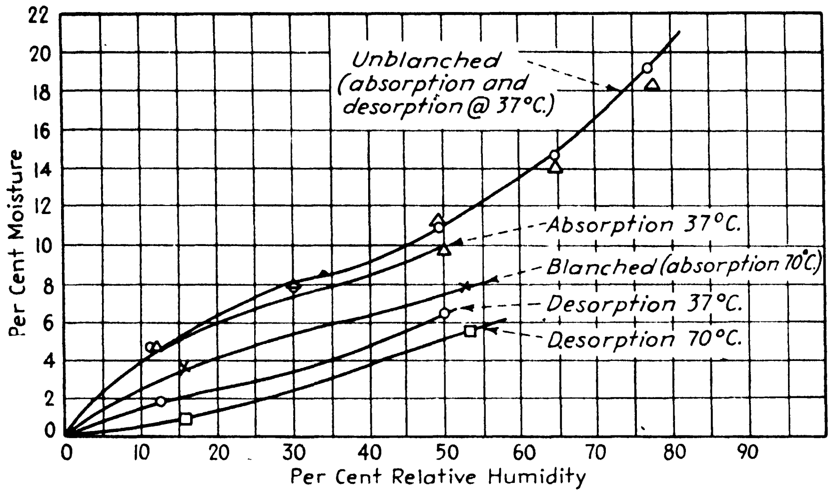


FIG. 52. Equilibrium-moisture curves for potatoes. [After Makower and Dehority: *Ind. Eng. Chem.*, 35, 193 (1943).]

gives the value for P_w. The value of $(\%\text{RH})_c$ is found from Fig. 52. Consulting this figure, it will be seen that dehydrated potatoes having 6 per cent moisture (which is the tentative Federal specification for dehydrated potatoes) will have a relative humidity of 20 per cent. This is called the *equilibrium moisture content* of the material, and means that potatoes containing 6 per cent moisture and stored in an atmosphere having 20 per cent relative humidity will neither absorb nor give up moisture; in other words, it is in equilibrium with water vapor in the storage space.

Then

$$VDP = 9.2\left(\frac{70-20}{100}\right), \text{ or } 4.6 \text{ mm}$$

* This does not take into consideration the material that must be lapped over to make a seal.

Referring to equation I above, it is preferable to use the inverted form of this equation, as this will give R (water vapor resistance) directly. Thus

$$R=\frac{A(VDP)t}{W-W_0}$$

and substituting the values found

$$R=\frac{0.56\times 4.6\times 180}{327}\text{, or } 1.4$$

R then equals 1.4, and from Table 66 should be selected a liner for which R is 1.4 or greater. Under the assumed storage conditions, any of the materials given in the table would be suitable.

As another example, let it be assumed that the same package is to be stored in a tropical country where the temperature would average 90° F and the average relative humidity would be 75 per cent. At 90° F the vapor pressure of saturated water vapor would be 36.1 mm of mercury. Then

$$VDP=36.1\left(\frac{75-20}{100}\right)\text{, or } 19.9 \text{ mm}$$

Substituting in the formula:

$$R=\frac{0.56\times 19.9\times 180}{327}\text{, or } 6.1$$

Thus R equals 6.1, and from Table 66 should be selected a liner for which R is 6.1 or greater. Several will be found to meet this condition. If storage were to be for one year in the above example, R would equal 12.4, and the number of satisfactory liners would be reduced.

It should be pointed out that carrots probably could not be packed in any of the liners given, because this vegetable should preferably be packed in an inert gas.

In packing dehydrated vegetables for the Army and for Lend-Lease requirements, certain specifications must be met. These are subject to sudden changes and therefore no useful purpose could be served by giving the latest available information here. Dehydrators interested in packing for the Army should address Contracting Officer, Chicago Quartermaster Depot, 1819 West Pershing Drive, Chicago, Ill.

Table 66. Coefficients of Water-Vapor Permeability and Resistance For Package and Lining Materials

(Pitman, Rabak and Yee)

Lining or Package		K	R
Asphalt-impregnated kraft bag, 5 ply. Wts 50, 65A, 50, 65A, 60. Single unit with stitched and waxed ends. Asphalt, 25 lbs wt per ream, basis 40 lb sheet.		0.21	4.7
Asphalt-impregnated kraft paper. 3 ply. Wts 40, 65A, 50. Same construction of the ends.		0.41	2.5
Two-ply asphalt-impregnated kraft paper laminated to a heavy muslin core. Seams sewed, but not specially sealed.		0.49	2.0
Cellophane, moisture-proof, heat-sealed, tranparent. Type 52, 300 gauge.			
	Single bag	0.23	4.3
	Double bag	0.068	14.7
Cellophane, moisture-proof, heat-sealed, transparent, 300 gauge.		0.4	2.5
Ditto, but 450 gauge		0.46	2.2
Cellophane, moisture-proof, heat-sealed, transparent. Laminated to a sulfite paper, and put in a 3″×3″×4⅝″ carton.		0.23	4.4
Cellophane, moisture-proof, anchor-coated, crimp-sealed. 300 gauge and made into triplex bag.		0.23	4.4
Ditto, but in a light-weight corrugated carton, 12 in cube size		0.07	14.2
Cellophane, moisture-proof, heat-sealed, transparent, laminated to 2-ply, machine-glazed kraft paper containing a layer of asphalt between plies. Seams heat-sealed, sewed and waxed with carnauba wax. In light-weight corrugated carton, 12 in cube size.		0.20	5.0
Cellophane, two sheets of No. 300 gauge, moisture-proof, heat-sealed, anchor-coated, transparent material laminated into single sheet.		0.13	7.6
Ditto, but in light carton, 12 in cube size		0.033	30.0
Unbleached, supercalendered sulfite, 25-lb basis weight per ream, waxed to 33 lbs with 135° MP wax.	Single bag	0.55	1.8
	Double bag	0.20	5.0
Ditto, but with special high MP wax, Sinlge bag		0.26	3.8
Glassine, two sheets of 25-lb basis wt paper laminated to final weight of 52 lbs. Original paper was coated in addition.			
	Single bag	0.73–0.088	14–11
	Double bag	0.023	43.0
Glassine, 18-lb basis weight, waxed to 24 lbs		0.35	2.9
Glassine, two sheets of 20-lb basis wt laminated with 5 lbs of adhesive to form 45-lb sheet. Packages provided with a lip thermo-seal.		0.14	7.1
Glassine, two sheets of opaque laminated to a finished wt of 45-lb basis wt. then laminated to a sheet of 450-gauge Cellophane of moisture-proof, heat-sealing, anchor-coated, transparent quality.		0.018	55.0
Vegetable parchment, double-waxed, 30-lb basis weight paper to 38 lbs.	Single bag	0.43	2.3
	Double bag	0.22	4.5
Waxed, nesting container with circular, snap-in lid. Av. dia. 3¼″, net height 1¾″. Single sample tested, partly filled.		0.12	8.3
	completely filled	0.21	4.8
Ditto, but lid rewaxed	partly filled	0.026	38.0
	completely filled	0.025	40.0
Rubber hydrochloride, (Pliofilm), laminated to kraft paper		0.20	5.0
Rubber hydrochloride, (Pliofilm) type 120NO		0.15–0.16	6.7–6.2
Rubber hydrochloride (Pliofilm), No. 140 gauge, in a light cor-corrugated carton, 12 in. cube size		0.12	8.3

None of the packaging material given in Table 66 is capable of holding a gas. In the case of some dehydrated vegetables, such as cabbage, carrots, spinach and other greens, it is believed desirable to pack in an inert gas such as carbon dioxide or nitrogen. The question as to which is the better has not yet been adequately answered. In general, however, it is believed that greens (including cabbage) should be packed in nitrogen, and that other pigmented vegetables,

Courtesy U. S. Dept. of Agriculture. (Photograph by Knell)

FIG. 53. Dehydrated carrots drop from an endless-belt conveyor into large tin containers. In their passage along the conveyor, they have been inspected by a corps of trained women.

such as carrots and sweet potatoes, should be packed in carbon dioxide. When green vegetables are packed in carbon dioxide, the green color fades, probably because of the destruction of chlorophyll caused by the acid reaction created by carbon dioxide, and to the formation of pheophytin.

The technique of packing in an inert gas requires considerable care. For successful packing, the sealed container should not con-

tain more than 2 per cent oxygen, and this determination should be made at least 12 hours after filling and sealing. If analyses are made immediately after sealing, the results will be too low and give the packer a false security. The Dehydration Committee of the Bureau of Agricultural Chemistry and Engineering has described three methods of packing in an inert gas:

1. **Carbon dioxide "snow" method.** Solid carbon dioxide is used, which may be readily purchased in 10-in cubes weighing about 55 lbs. The material is ground in a coffee grinder to obtain the "snow." Gloves should be worn when handling solid carbon dioxide to prevent injury to the hands, since the material will cause burns. The snow is taken up with a scoop holding about ¼ lb; this amount is put in the bottom of a 5-gal can in which the vegetable is to be packed. Care is taken to distribute the "snow" evenly over the bottom of the can. The vegetable is then weighed into the can, the lid (containing a $\frac{1}{16}''$ vent hole) put loosely in place, and the can placed in a trough containing from 4 to 6 inches of water. The purpose of the water trough is to permit melting of the "snow." There is a rapid evolution of gas which escapes around the cover, and since carbon dioxide is heavier than air, the latter will be expelled from the can. One-quarter of a pound of "snow" will, upon "melting," generate 2 cu ft of carbon dioxide which is over three times the volume of the 5-gal can. After the excess gas has escaped (which will be from 6 to 12 min), the can is sealed. When the rush of gas through the vent hole has subsided, the hole is sealed with a drop of solder.

There are certain hazards to this method, two of which are mentioned by the Committee: frost-nipped hands, and bursting cans from too early capping. If the "snow" is too coarse, evolution of gas is slower than with fine "snow" and a longer time must be allowed before final capping and soldering. A hazard not mentioned is the presence of oil in solid carbon dioxide, originating from the compressors used in making it. The oil may impair the flavor of the product.

Vacuum-Bell Method. This involves the removal of air from the can and replacing it with an inert gas. The equipment required is similar to that used in regular canning operation. The cans are placed on a flat metal plate, one side of which is machined true. A heavy metal bell, counterpoised, is placed over the can, and the air evacuated from beneath the bell. An orifice in the line from the bell

space to the vacuum pump is so adjusted that the air will not be removed from outside the can fast enough to cause it to bulge or subsequently collapse. The can is filled with the commodity being packed, the cover put in place but not sufficiently tight to prevent escape of air, and the can placed beneath the bell. A vacuum of 29 in is drawn and immediately released with an inert gas. A posi-

Courtesy U. S. Dept. of Agriculture. (Photograph by Lee)

FIG. 54. An operator replaces the air in a tin container in which freshly dehydrated cabbage has been packed with an inert gas (carbon dioxide or nitrogen). All cabbage processed for our armed forces and for Lend-Lease purchases is packaged in an inert atmosphere, to prolong storage life.

tive pressure of 1 to 2 in is placed on the bell to be certain that the vacuum has been released. The bell is then raised and the can removed and sealed in a standard can-closing machine equipped with a head suitable for sealing the 5-gal cans used.

Cylinder and Meter Method. This is perhaps the simplest. It consists of purging the can with a specified amount of an inert gas. This is accomplished by thrusting a purge tube (a metal tube

attached to a small rubber hose) to the bottom of a 5-gal can containing the vegetable. The rubber tube is connected to a gas meter and the meter to a cylinder of the inert gas. The lid of the can is slid over the can opening as far as possible and two cubic feet of gas (as measured by the meter) are allowed to flow into the can. The tube is then removed, and the can sealed. In the case of carbon dioxide, 2 cu ft will give a residual oxygen content of from 1.5 to 1.8 per cent; with nitrogen, residual oxygen may be in excess of 2 per cent.

Courtesy U. S. Dept. of Agriculture. (Photograph by Lee)

Fig. 55. An operator hermetically seals a tin can filled with dehydrated cabbage in which air has been replaced by an inert gas.

In factory practice, the proper amount of gas introduced is usually judged by the time required to extinguish a flame held at the mouth of the can. This method may occasionally result in residual oxygen contents of less than 2 per cent, but the technique is crude and uncertain.

In gas-filling cans, it should be borne in mind that the containers are usually sealed at atmospheric pressure found at sea level. If such cans are taken to higher altitudes, the pressure within the can will be increased. For instance, at an altitude of 5000 ft, such a can would have an internal pressure of about $2\frac{1}{2}$ lbs. gauge. It is thus

necessary to have all seals tight. If leaks occur due to pressure within the can, part of the gas will escape, and when such cans again return to sea level the gas lost will be replaced by the air which will be sucked in. This may result in as much as a 4 per cent increase in the oxygen content of the can.

Packing of Dried Eggs

Dried eggs are commonly packed in barrels containing from 120 to 250 lbs, the 175-lb barrel being most widely used at present.

Courtesy U. S. Dept. of Agriculture. (Photograph by Forsythe)

Fig. 56. Some of the dried eggs made in the United States for the United Nations is put up in consumer-size packages. A mechanical conveyor carries empty boxes to operators, who fill them from the filling machine (left).

The product, as it comes from the spray-dryer, is hot and cannot be packed until it is cool. The eggs are sometimes cooled by means of a spiral conveyor which at the same time breaks up the lumps of powder. At the end of the conveyor, the dried product may fall on

a shaker and then into the barrel in which it is to be packed. If a conveyor is not used, the dried eggs fall from the dryer through a sifter and then into shallow trays where they are cooled by stirring before being put into the barrel.

Barrels are of soft wood, such as fir, elm, poplar or soft maple, and with a double liner of waxed parchment. The outer liner is waxed to 45 lbs, the inner liner to 15 lbs. The small, inner liner is slack-filled and two liners are then folded together at the top.

Dried eggs may also be packed in 25- to 30-lb cases, and in tins ranging from 1 to 25 lbs. Large quantities of whole egg powder are packed in 5 ounce individual packages using an envelope of "Thermophane," or a similar material, the envelope in turn being sealed in a carton. Each package is equivalent to one dozen eggs, and they are packed 24 to 48 to a wooden carton.

Packing of Dry Milk

It is necessary to pack dry milk in air-tight, moisture-proof containers to protect the product from oxidation and absorption of moisture. Two hundred-pound barrels are the usual bulk containers, and it is recommended that these be coated inside with paraffin, sodium silicate or a casein preparation. Liners similar to those described for dried eggs are used.

Whole dry milk is packed in 1-, 5-, 25- and 50-lb tin cans which are evacuated, the vacuum replaced by nitrogen, and then the containers vacuum sealed.

As in the case of dried eggs, milk powder must be cooled before it is packed in the final container. Prolonged exposure of the product to high temperatures injures the flavor, encouraging tallowiness, and decreases the storage life. Drum-dried milk is usually cool before it is ready for packing, and no special cooling technique is necessary. Spray-dried milk, on the other hand, must be cooled after leaving the drying chamber; one method of accomplishing this is by blowing refrigerated air into the powder as it is sucked from the dryer. A so-called Ramshorn pump is used for this purpose, the piping of which is so arranged that the powder is reduced to fine particles. These particles are blown to a dust collector, then to a hopper from which they drop to a flour bolter into the final barrel mounted on a shaking platform.

Packing of Dry Beef Serum and Hemoglobin

Standard packages are 50-lb tubs and 200-lb barrels with a kraft paper liner. The product should be cooled before packing to prevent lumping.

Dehydrated Meat

Successful packaging material other than the tin can, has not as yet been found for this product, which offers the same difficulties as dehydrated vegetables. In the case of meat, the fat present offers considerable trouble because of the danger of rancidity. A laminated kraft paper, lead-coated on one side and containing a laminated Cellophane inner liner over the lead coating may have possibilities.

Storage of Dried and Dehydrated Fruits

Because of their high sugar and acid content, deterioration of dried and dehydrated fruits during storage is not a serious factor provided the fruit has been properly packed as already described. Storage should, of course, be in a cool, dry place. Table 67 indicates the most favorable temperature and relative humidities for storage of some dried fruits.

Table 67. Storage Conditions for Some Dried Fruits
[*Barger, Western Canner and Packer*, **33**, *No. 11, 57 (1941)*]

Fruit	Temp (°F)	Rel. Humidity (%)
Apples	32–45	70–80
Apricots	32–45	70–80
Figs	32	50
Pears	32–45	70–80
Peaches	32–45	70–80
Prunes, regular	60	<70
Prunes, red sugar	45 32	70 70–80
Raisins	60	<50

< less than

Storage of Dehydrated Vegetables

The storage of dehydrated vegetables under such conditions as to prevent deterioration of their quality, both from the nutritive and flavor standpoint, is a problem with which food technologists are still struggling. Temperature is an important factor in the storage life, and the lower the temperature of storage, the longer the expected life of the product. Pitman, Rabak and Yee[1] suggest that

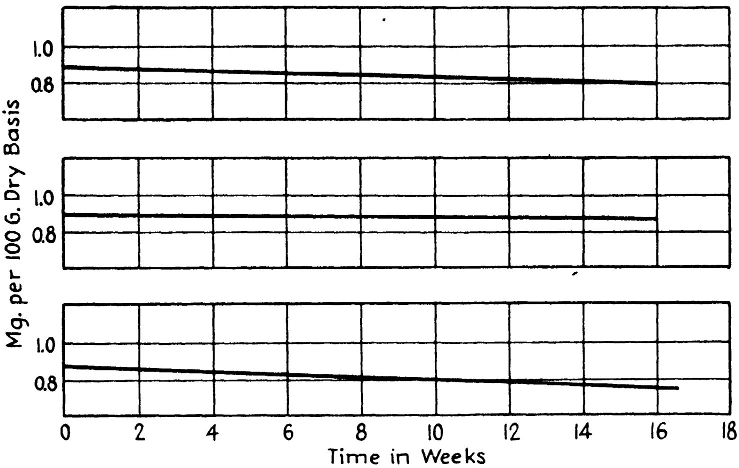


FIG. 57. Riboflavin loss in dehydrated cabbage stored in air at 90° F. (After Chace).

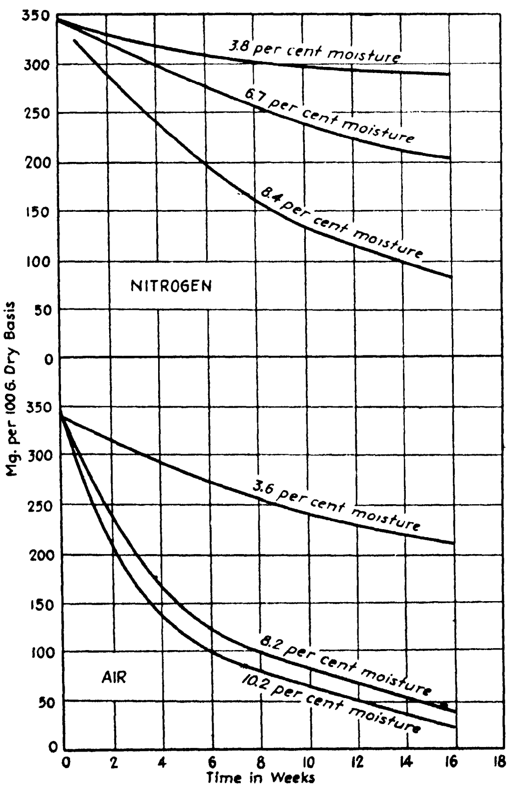


FIG. 58.
Ascorbic acid loss in dehydrated cabbage stored in nitrogen and air at 90° F. (After Chace).

light probably accelerates destructive reactions in dehydrated vegetables. This would perhaps be of importance in packages for civilian use if the contents were displayed for consumer information, but at present all packages of dehydrated vegetables are not subject to display. In the case of certain dehydrated vegetables, oxygen and the resulting oxidation is certainly an important factor in the keeping quality of the product. Moisture content of the material is probably the most important factor in storage life. It is quite obvious that the moisture content must be below that necessary to support mold or bacterial growth. Experiments by the Dehydration

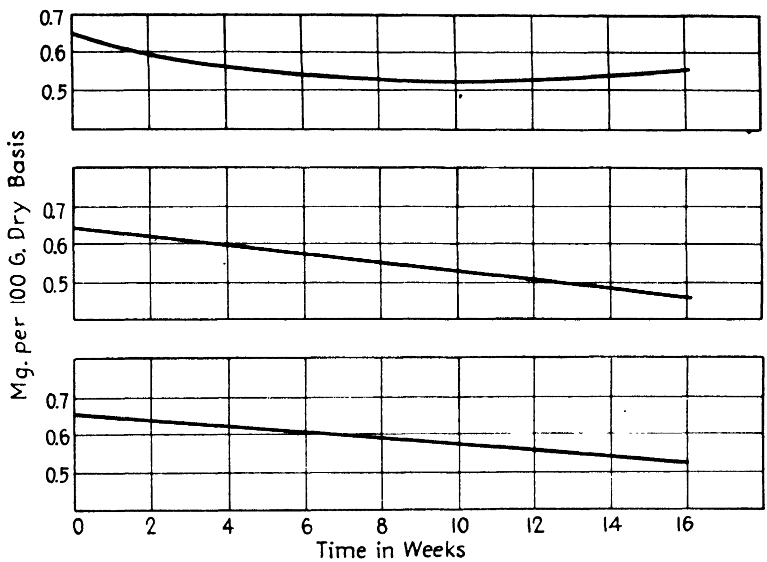


FIG. 59. Thiamin loss in dehydrated cabbage stored in air at 90° F. (After Chace).

Committee of the Bureau of Agricultural Chemistry and Engineering of the U. S. Department of Agriculture [3] have shown that the life of cabbage, for instance, stored at 90° F, and determined by the retention of vitamin C, is increased 50 per cent for each 1 per cent decrease in the moisture content. This retention held true over the range of 12 to 3 per cent moisture.

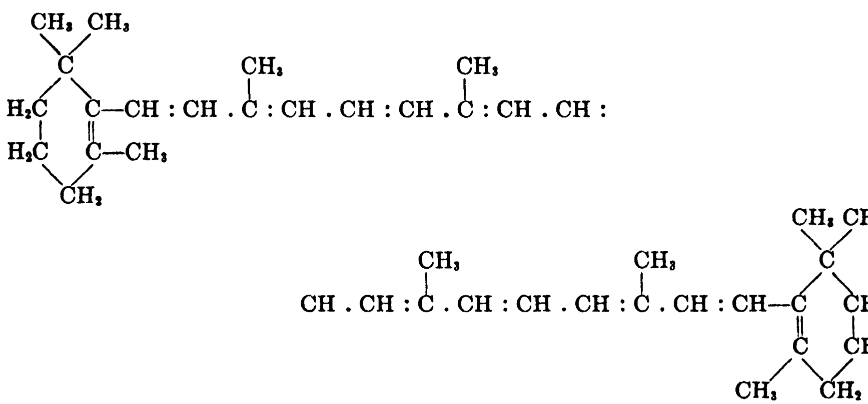
During storage of dehydrated vegetables, there is a decrease in vitamin content and palatability, the extent of this decrease depend-

[3] Anon., "Information Sheet on Packaging and Storage of Dehydrated Vegetables," *U. S. Dept. Agr., Bur. Agr. Chem. & Eng.* ACE-185 (Oct. 3, 1942).

ing upon storage temperatures, moisture content of the product, and the particular vitamin, and whether or not air is present in the packaged material. Storage may also bring about a change of color. Thus, potatoes containing about 9 per cent moisture and stored at 90° F will assume a brown color; spinach packed in carbon dioxide will become a dirty green due to the reduction of chlorophyll to pheophytin, and carrots may bleach to a pale yellow or white.

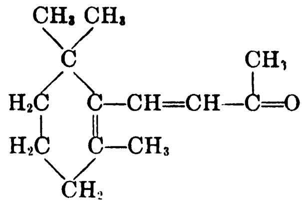
Chace [4] has reported the fate of some dehydrated vegetables when stored at various moisture contents and in different gases and at temperatures of 90° F. Some of his data are shown graphically in Figs. 57, 58 and 59.

The cause of the flavor changes which occur in stored dehydrated vegetables has not as yet been adequately explained. The most prevalent theory is that such off-flavors are due to enzyme action. If so, they must be brought about by enzymes which at present we cannot readily detect. There are cases, too, where certain unblanched dehydrated vegetables (in which enzymes have presumably not been destroyed) have retained their quality as well as, if not better, than blanched vegetables of the same variety. On the other hand, unblanched dehydrated carrots will often assume a violet flavor upon storage. This is no doubt brought about by oxidation (rather than by any enzyme action) of β-carotene, with the formation of β-ionone, the structure of which is quite similar to that of carotene;



Structure of Carotene.

[4] Chace, E. M., "The Present Status of Food Dehydration in the United States," *Proc. Inst. Food Techn.*, p. 70, (1942).



Structure of β-Ionone.

From the structural formulas, it will be seen that β-carotene has two β-ionone rings. β-ionone has a powerful violet-like aroma.

Dehydrated spinach is quite likely to develop a hay-like odor which may be due to minute amounts of coumarin. What causes this off-flavor and the true nature of the substance responsible are unknown.

Some authorities believe that those vegetables containing high percentages of pectin are less likely to develop off-flavors during storage than those containing little pectin, the pectin apparently acting as a protector against oxidation. In practice, this has been partly substantiated by the fact that beets, which are high in pectin, do not seem to develop off-flavors readily during storage.

From Chace's data [4] it will be seen that the lower the moisture content of the product, the less the destruction of vitamins. It is possible that should the moisture content be reduced to one per cent, or even lower, the storage life of dehydrated vegetables would be prolonged. It is a question whether this low moisture content could be economically attained by our present commercial methods of dehydration.

Mitchell and Lease [5] have studied the stability of carotene in sweet potato flour, and have found that when the flour is stored

Table 68. Stability of Carotene in Sweet Potato Flour as Affected by Method of Storage
(*Mitchell and Lease*)

Method of Packing	Carotene Content after Various Storage Periods: Initial	4 mo	8 mo	12 mo	Loss during one year (%)
	(milligrams per gram)				
In hermetically sealed cans					
under carbon dioxide	158.0	119.0	119.0	131.0	17.1
under nitrogen	158.0	119.0	128.0	119.0	24.0
vacuum (15 mm)	158.0	.....	123.0	119.0	24.0
sealed in air	158.0	.....	17.3	17.4	89.0
In loosely stoppered bottles	158.0	8.8	5.37	2.37	98.5

[5] Mitchell, J. H., and Lease, E. J., "Stability of Carotene in Dehydrated Sweetpotatoes," *So. Carolina Agr. Exp. Sta. Bull.* 333 (1941).

exposed to air loss of carotene is rapid, but that when air is excluded or replaced by carbon dioxide, carotene is stable. Their results are given in Table 68. It should be pointed out that these workers did not blanch the potatoes before dehydration.

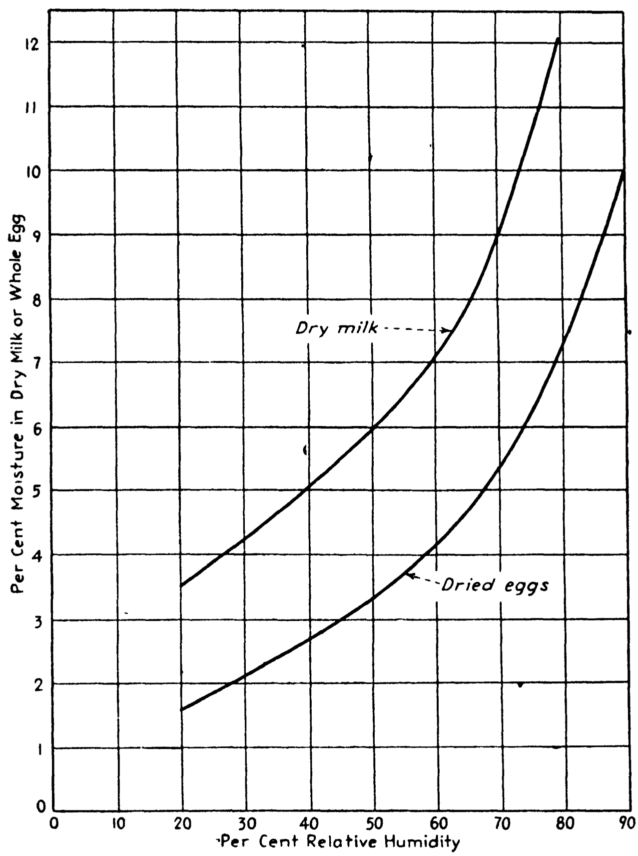


FIG. 60. Equilibrium-moisture content of dry milk and dried whole eggs. (Milk data after Supplee; egg data after Stuart, Hall and Dicks.)

STORAGE OF DRIED EGGS

Stuart, Hall and Dicks [6] have recently published their work on the changes taking place during the storage of spray-dried eggs. The maximum safe humidity at which the product should be stored, according to these workers, is 65 per cent when the temperature is

[6] Stuart, L. S., Hall, H. H., and Dicks, E. E., "Storage Changes in Spray-Dried Whole Egg Powder," *The U. S. Egg and Poultry Mag.*, **48**, No. 12, 629 (1942).

30° C (86° F). No bacterial growth was found to have taken place in any of their samples stored at relative humidities of 90 per cent or less, when the dried eggs contained 10 per cent or less of moisture. It was found that mold will not grow if the eggs are stored at relative humidities of 85 per cent or less. Changes in solubility were more pronounced when the product contained more than 5 per cent moisture than when it contained less than this amount. From these researches, the most important single factor in the preservation of quality in dried eggs during storage is control of moisture content. Thus, it is important to produce an egg powder containing not more than 5 per cent moisture, and to store under such conditions as to prevent moisture absorption.

We know little about the fate of vitamins during the storage of egg products. Work of this nature is now under way, but data are not sufficiently complete to draw conclusions.

Dried eggs do not attract insects, but after long storage they may become infested with flour beetles, larder beetles, and certain dermestids of the genus *Trogoderma*. Such infestations are, however, extremely uncommon.

Storage of Dry Milk

Improperly stored dry milk will decrease in solubility, and off-flavors will develop. It is a well-known fact that the solubility of dry milk will decrease with age, and this decrease becomes more pronounced with an increase in moisture content. It is probable that this is due to certain physico-chemical changes of the protein (casein) of the milk in the presence of moisture. Dry milk should have an initial low moisture content and should be stored to prevent subsequent moisture absorption.

Besides decreased solubility of dry milk during storage, the product may develop odor and flavor defects such as staleness, mustiness, rancidity, and tallowiness. Even fishy odors may develop. It is believed that these defects are brought about by enzymes, or chemical reactions involving oxidation, hydrolysis and catalysis.

Stale and musty flavors are hastened by moisture and the temperature of storage: high temperatures induce a stale flavor, and low temperatures a musty flavor. These defects appear to be more prevalent in drum-dried milk than in spray-dried. Although the

nature of the reaction is not known with certainty, it is believed to be caused by some change in the protein.

Rancid flavors are due to hydrolysis of the fat, probably by the enzyme lipase, with the liberation of fatty acids. Such milks have a butyric odor. Supplee [7] added lipolytic enzymes to milk powder, and the product thus treated developed an intense rancid flavor in a few weeks, while the control did not become rancid. Since lipase is quite resistant to heat, and if the rancidity is caused by this enzyme, then dry milk prepared by processes using high temperatures should be less liable to this defect than those prepared at low temperatures. This has been found to be the case, for drum-dried milks rarely develop rancidity, whereas spray-dried milks are quite likely to do so. The control of rancidity lies in heating the milk to a temperature sufficiently high to destroy lipase. However, if the milk were dried at temperatures higher than commonly used, the solubility of the product would be injured. It has therefore been suggested that the milk be preheated at such temperatures as to render lipase inactive. Nair [8] preheated fluid milk at approximately 65° C (148° F) for 30 min and could not detect lipase in the dried product obtained from this milk.

Tallowy flavors are the most prevalent defect of stored, dry whole milk, but are not troublesome in dry skim milk. The phenomenon has been studied by Holm and Greenbank,[9] Supplee,[7] Hunziker and Hosman,[10] Holm, Greenbank and Deysher,[11] and others. It is caused by oxidation of the unsaturated fatty acids in the milk fat, notably oleic acid. The fat does not absorb oxygen immediately, but there is an induction period, the length of which serves as an index of the keeping quality of the fat. The reactions are not well understood, but the general nature is thought to be as follows [12]:

[7] Supplee, G. C., "The Keeping Quality of Dry Milk," *Proc. World's Dairy Congress,* Washington, D. C., II (1923).

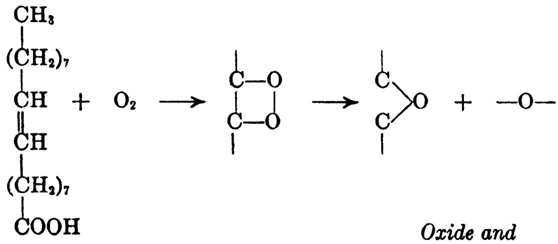
[8] Nair, J. H., "Lipase in Raw, Heated and Desiccated Milk," *Ind. Eng. Chem.*, 22, 42 (1930).

[9] Holm, G. E., and Greenbank, G. R., "The Keeping Quality of Butterfat with Special Reference to Milk Powder," *Proc. World's Dairy Cong.*, Washington, D. C. II (1923).

[10] Hunziker, O. F., and Hosman, D. F., "Tallowy Flavor in Butter," *J. Dairy Sci.*, 1, 77 (1928).

[11] Holm, G. E., Greenbank, G. R., and Deysher, E. F., "Susceptibility of Fats to Oxidation," *Ind. Eng. Chem.*, 19, 156 (1927).

[12] Associates of Lore A. Rogers, "Fundamentals of Dairy Science," 2nd Ed., Reinhold Publishing Corp., New York, 1935.



Oleic acid *Peroxide* *Oxide and active oxygen*

The active oxygen then probably forms an ozonide by uniting with the peroxide. The ozonide formed is unstable and breaks up to form one molecule of an aldehyde, or the corresponding ketone and one molecule of an acid.

As tallowiness is caused by oxidation, its onset is delayed by packing dry milk in a vacuum or in an inert gas. Carbon dioxide is not inert toward milk fat [12] and packing in this case is of little value. Unfortunately, even minute amounts of oxygen and loosely bound oxygen compounds, called moloxides,[12] will eventually cause a tallowy flavor. Nitrogen- or vacuum-packing reduces the tendency of the product to acquire this flavor.

Light, in the presence of air, is a factor in promoting tallowiness, especially the shorter wave lengths in the region of the ultraviolet.[13]

As already pointed out, tallowiness increases with increased storage temperatures of the milk. Dahle and Palmer [14] studied the effects of temperature on the keeping quality of whole dry milk powder and found that milk packed in air-tight containers did not become as tallowy as that not so stored. Some of Dahle and Palmer's results are summarized in Table 69.

Table 69. Time at Which Milk Powder Becomes Tallowy When Stored at Different Temperatures
(*After Dahle and Palmer*)

Temp. of storage (°F)	Time of Storage: 3 mo	9 mo	12 mo
39.12	−	−*	+
68	−	sl. +	+
98.6	+	+	+

− no tallowy flavor
+ tallowy flavor
* one of the samples had a tallowy flavor

[13] Hunziker, O. F., "Condensed Milk and Milk Powder," 5th Ed., p. 560, 1935

[14] Dahle, C. D., and Palmer, L. S., "Some Factors Affecting the Keeping Quality of Whole Milk Powders," *J. Dairy Sci.*, **7**, 1 (1924).

In view of the data of Dahle and Palmer and others, it is apparent that milk powder should be stored at as low a temperature as possible. Permitting the dry milk to remain in the drying chamber at the temperatures prevailing there, or packing hot, will also encourage the development of tallowy flavor.

The role of moisture in the onset of tallowiness has been much disputed. Holm and Greenbank[9] found that even extremely dry milk powders would develop off-flavors before those of high mois-

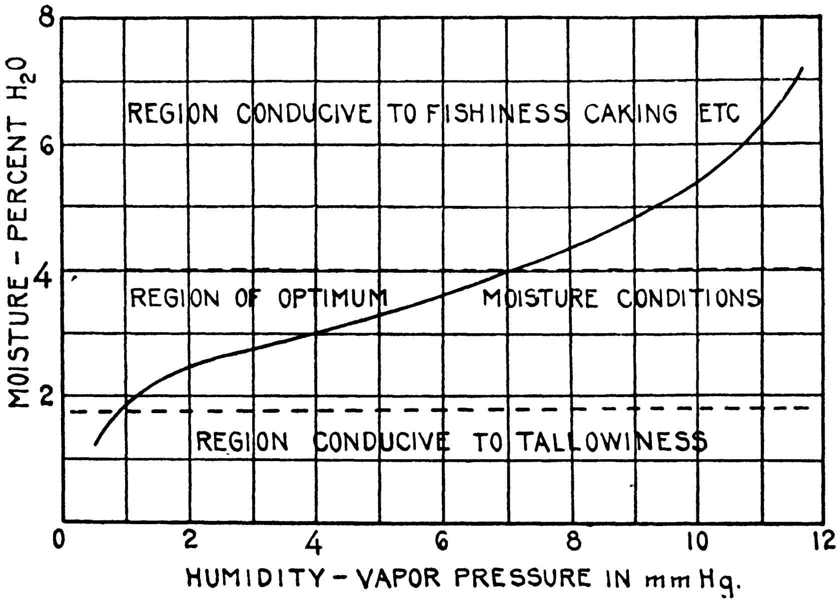


FIG. 61. Moisture—vapor pressure equilibrium curve for dry whole milk. (From Associates of Lore A. Rogers, "Fundamentals of Dairy Science," p. 92, 1935. Reinhold Publishing Corp.)

ture content. However, powders with high moisture develop fishy rather than tallowy odors. Later Greenbank and Holm[15] presented evidence indicating that moisture has a retarding action upon the oxidation process causing tallowiness, probably by preventing the formation of aldehydes and ketones. Fig. 61 shows Holm and Greenbank's representation of the relation of moisture content of dry milk and vapor pressure to changes that occur.

Contradictory evidence is found regarding the effect of fat on tallowiness. Supplee[7] states that, beyond certain limits, the higher

[15] Greenbank, G. R., and Holm, G. E., *Ind. Eng. Chem.*, 16, 598 (1924).

the fat content of the dry milk, the longer the time is required for the product to become tallowy. Holm, Greenbank and Deysher [16, 17] report that increased fat content of milk powder increases the susceptibility of the product to oxidation, and that above 24 per cent fat content, the increase in susceptibility is rapid with additional increase in fat. Hunziker [18] has summarized Supplee's results, as shown in Table 70.

Table 70. Effect of Fat Content on Length of Time Before Tallowiness Appears in Dry Milk

(*After Hunziker*)

Kind of Milk	% Fat	Time to produce tallowy condition
About ¾ skim	5–6	Almost always tallowy after 3 to 4 mo
½ skim	12–13	Rarely under 5-6 mo; more often not until 7–8 mo
Whole milk	26–27	Kept satisfactorily for 12-13 mo
Thin cream	50–55	" " " 15-18 mo

Acidity will hasten the onset of tallowiness, since acids are catalysts for the oxidation reactions responsible for this condition.[18] Thus, it is important to use a fluid milk of low acidity, as previously pointed out (p. 147). Subjecting the milk to high temperatures during drying will reduce the acidity, and for this reason drum-dried milk is lower in acidity than spray-dried. The product made by the former method does not become tallowy so readily as that made by the latter.

Metals, especially copper, act as catalyzers of tallowiness. For example, copper salts, even in such small proportions as 10 to 15 ppm.[7] Oxides of iron, platinum, silver, nickel, cobalt, vanadium, cerium, chromium, uranium and lead also act as catalysts.[12]

Other important factors in the development of tallowiness are: character of the powder grain, for the greater the surface area of the grain, the more likely the product to become tallowy; and evaporation of the milk before drying, since evaporation retards the onset of tallowiness, as does homogenization of the milk before drying. Hunziker [19] claims that sucrose will retard tallowiness.

Dried buttermilk, because of its high acid and low fat content, keeps better than either whole or skim milk powder.

[16] Holm, G. E., Greenback, G. R., and Deysher, E. F., *J. Dairy Sci.*, **8**, 515 (1925).
[17] Holm, G. E., Greenbank, G. R., and Deysher. E. F., *ibid.*, **9**, 512 (1926)
[18] Greenbank, G. R., and Holm, G. E., *Ind. Eng. Chem.*, **16**, 598 (1924).
[19] Hunziker, O. F., "Condensed Milk and Milk Powder," 5th Ed. Published by the author, La Grange, Ill., 1935.

Fishy flavors may develop in milk powders of high moisture content. Researches by Supplee,[7] Cusick[20] and others have shown that this is due to the formation of trimethylamine brought about by the hydrolysis of lecithin. Metals accelerate this hydrolysis. Fishy odors are not due to bacterial decomposition, and enzymes are involved only indirectly.

Storage of Dehydrated Beef Serum and Hemoglobin

High storage temperatures will decrease the solubility of both these products. Table 71 shows the effect of storage temperature on the solubility of dry beef serum.

Table 71. Effect of Storage Temperatures on the Solubility of Dry Beef Serum (*von Loesecke*)

Age of Sample (days)	Moisture (%)	% Insoluble matter when stored at 86°F	67°F	51 8°F
0	5.6	0.7	0.7	0.7
36	"	9.9	0.7	trace
52	"	45.0	0.7	"
95	"	50.0	0.7	"
123	"	55.0	0.7	"
160	"	60.0	0.7	"

Compression of Dehydrated Foods

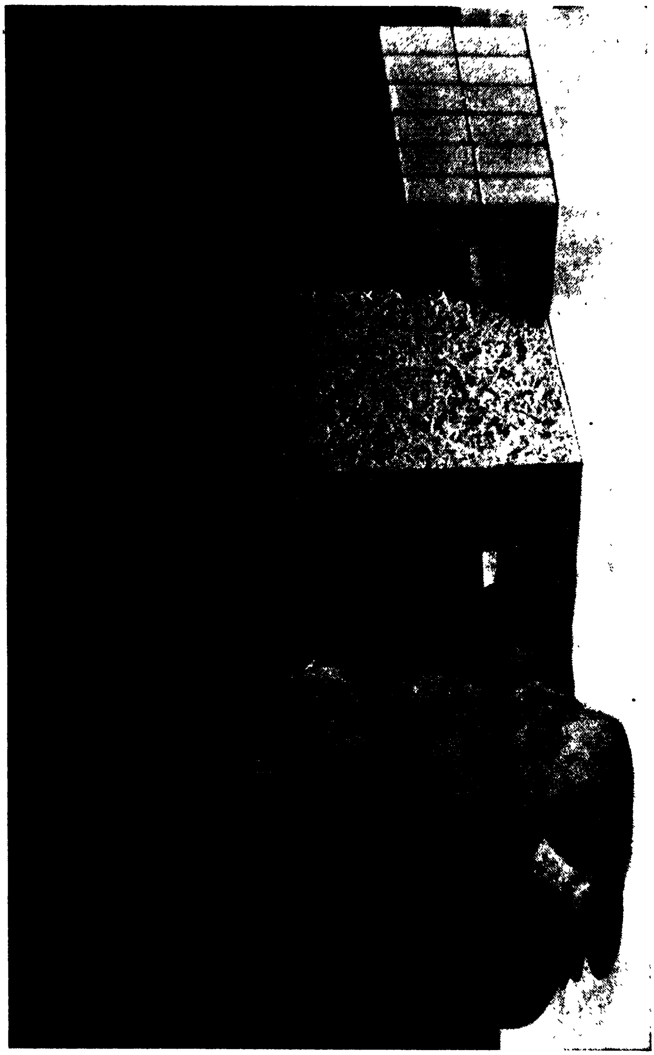
Compression of vegetables to decrease their volume is still largely in the experimental stage. Leafy vegetables such as spinach and cabbage must be compressed when they still contain more water than is desirable for the best keeping qualities. If they are too dry, the product will be shattered to a powder. Cabbage, for instance, must contain about 10 per cent water to be compressed and the compressed material must then be further dehydrated until it contains not more than 4 per cent water. To dry compressed cabbage is nearly impossible, and all the vitamin C is lost during this second dehydration. According to present methods, compression of dehydrated white potatoes causes rupturing of the cell walls, thus releasing the starch. Such potatoes, when reconstituted, will be pasty.

Pressures used in compression vary from about 700 to 2000 lbs per sq in. In some instances, certain vegetables, such as carrots and cabbage, can be compressed with a fair degree of success if the product is heated to about 180° F during pressing.

Powdered products, such as soups, whole milk and eggs, can be

[20] Cusick, J. T., *Cornell Univ. Exp. Sta. Memoirs*, 30 (1920).

readily compressed; and according to Kraybill[21] dehydrated meat can be compressed by using pressures of 1500 to 2000 lbs per sq in. Powdered whole eggs can be compressed by using pressures of about



Courtesy Chemical and Engineering News

FIG. 61*a*. At left are nine pounds of raw potatoes. At center, in exhibit container, is the equivalent amount after shredding and dehydrating have reduced them to 18 ounces. Squeezing in an hydraulic press further reduces volume by 75 per cent, shown by block of 12 cakes at right. Each cake makes servings for two people.

700 lbs per sq in. Excessive pressures will express the oil. Dry skim milk cannot be compressed because the compressed product will not reconstitute.

[21] Kraybill, H. R., "Dehydration of Meat," *Ind. Eng. Chem.*, 35, 46 (1943).

Suggested Readings

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Chapter 10

Methods of Analysis, and Reconstitution of Dehydrated Foods

Fruits

Moisture may be determined by the standard vacuum-oven method as given in "Official and Tentative Methods of Analyses of the Association of Official Agricultural Chemists," * or by special electrical instruments, descriptions of which may be obtained from the California Fruit Association in San Francisco. One type of instrument has been used for several years in the California dried fruit industry, and it has been shown to be accurate to within a few tenths of a per cent. However, the vacuum-oven method is official, but requires about 6 hours for completion and calls for considerable expensive apparatus. Moisture determinations by the instrument method may be completed in a few minutes.

Sand. This determination is made chiefly in the case of raisins. A representative sample is ground in an ordinary food chopper. Two hundred fifty grams of the ground sample are mixed with 1900 cc of distilled water and boiled while stirring. Saturated sodium chloride is then added and the material that floats is skimmed off. The residue is "panned" with brine until free from raisin particles and the sand filtered through a carefully prepared Gooch crucible, washed with distilled water until free from chlorides, ignited, cooled and weighed.

Mold on raisins is determined by adding 3 per cent hydrogen peroxide. If mold is present, bubbles of oxygen will be given off. Mold can, of course, be determined by recognized bacteriological technique, but this is not done in routine examinations.

Free Sulfur Dioxide. This is determined by distilling a mixture of the ground fruit with distilled water, acidified with a few cubic centimeters of hydrochloric or phosphoric acid, into a standard

* This may be obtained from the Association of Official Agricultural Chemists, Washington, D. C. (price, $5.00).

solution of iodine. Excess iodine is titrated with standard sodium thiosulfate. For detailed directions the reader should consult the Official Methods of the Association of Agricultural Chemists.

Total Sugars are determined according to the Official Methods.

Insect Damage. Usually such damage can be seen with the unaided eye, or at least with a low-power lens. Portions of the fruit will be eaten away, or pellets, webbing or frass will be present. For details, the reader should consult "Testing Dried Fruit" by B. J. Howard, *U. S. Dept. Agr., Food and Drug Admins.* Pub. 4 (Microanalytical Div.) (1935).*

VEGETABLES

Moisture. There is no accurate, rapid method for determining moisture in dehydrated vegetables. Instruments used for determining moisture in dried fruits are not generally applicable to dehydrated vegetables. There are some instruments available for measuring the moisture content of dehydrated vegetables, and great accuracy is claimed for them. All such apparatus must be standardized for each product in which moisture is to be determined. Dehydrators contemplating the use of such instruments should investigate thoroughly before purchasing, and if they are used, the results obtained should be occasionally checked against the vacuum-oven method as applied to dried fruits.†

One method quite often used is a modification of the Bidwell-Sterling procedure for the determination of moisture in grains and feeds, and is the subject of much criticism. This method does not require an expensive array of apparatus, and if directions are followed, it will yield reliable and reproducible results. The apparatus is shown in Fig. 62. A representative sample of the dehydrated vegetable is ground in a meat chopper, using the finest knife. From 25 to 30 grams (accurately weighed) of the ground materials are introduced into the flask of the distilling apparatus. About 120 cc of toluene are added to the flask and the apparatus connected. The receiving tube is filled with toluene by pouring through the top of the condenser. The toluene in the flask is brought to a boil by means of an electric stove, and the distillation allowed to proceed slowly

* The Food and Drug Administration is no longer a part of the Department of Agriculture, but a branch of the Federal Security Agency.

† There is no official vacuum oven method for dehydrated vegetables.

so that about 2 drops per second fall from the end of the condenser. This rate of distillation is continued for 20 min; it is then increased so that 4 drops per second fall from the condenser, and this rate is continued for 10 min. The distillation is then stopped and the condenser washed by pouring in toluene at the top. If any water remains in the condenser tube, it is removed by brushing with a test-tube brush soaked with toluene. The receiving tube is allowed to come to room temperature, and if any drops adhere to the sides

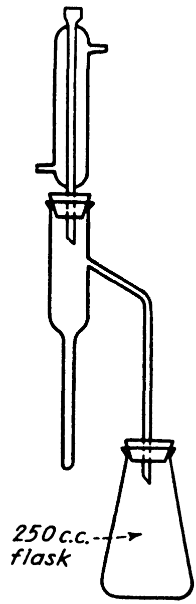


FIG. 62.
Bidwell-Sterling apparatus for determining moisture in dehydrated vegetables.

of the tube, they are forced down by means of a rubber band wrapped around a copper wire. The volume of water (in cubic centimeters) is then read and the per cent water calculated.

It should be borne in mind that toluene is inflammable and that its vapors are toxic. To insure accurate results the sample must be finely ground and time and rate of distillation must be as specified. Benzene may be used in place of toluene, but distillation is then for one hour instead of 30 min.

The method should be checked against the vacuum-oven method as applied to dried fruits.

Enzymes. The test for the destruction of the enzymes catalase and peroxidase has caused much trouble and confusion, especially

in the case of the latter. Although considerable emphasis has been placed on the importance of enzyme destruction in the proper blanching and dehydration of vegetables, there is no reliable qualitative test to indicate their destruction. It should be pointed out that these two enzymes have been selected merely as indicators of the thoroughness of blanching. Whether they have anything to do with the deterioration of the dehydrated product is unknown. The method now used for the detection of peroxidase depends upon a color reaction using either benzidine or guaiacol. Benzidine is less specific than guaiacol and will give a positive test with hemin, iron salts, nickel and several other metallic salts. Guaiacol will react with lignin, giving a false test for peroxidase. Such a test will be indicated by a spotty color and will not be uniform throughout the sample. It has therefore been suggested that peroxidase tests with guaiacol be carried out on the filtered sample. However, this has not been accepted by those inspecting dehydrated vegetables for Federal purchases. It is maintained, moreover, that blanching should be sufficient to destroy even the positive test for lignin. To obtain this would require, in many cases, cooking rather than blanching. Guaiacol cannot be used with carrots. For instance, unblanched dehydrated carrots will not give a color test; and the color is masked in the case of beets by the color of the beets themselves. Benzidine, in many instances, will give a positive test with potatoes that have been blanched as long as 15 min. Rutabagas will also sometimes give positive tests with benzidine even though they have apparently been adequately blanched.

For information regarding enzymes in processed foods and the uncertainty of testing for them, the reader should consult "The Fate of Enzymes in Processed Foods," by A. K. Balls, *Fruit Products J.*, **22**, No. 2, 36 (1942).

In testing for catalase and peroxidase, two controls should be run with every determination. One control is for the reagents (without the dehydrated vegetable) and the other on the completely inactivated material. Both controls must be tested under the same conditions. It is also important to add the specified amount of reagents, because the concentration of the reagents has a direct influence upon the sensitivity of the test.

If the material has been completely inactivated, the reaction obtained will be the same as on the reagents alone. It is better if

all tests and controls are run in duplicate. All glassware should be scrupulously clean and only distilled water should be used. In carrying out the test, dehydrated material should be reconstituted by soaking in water for 15 to 30 min and then ground so that all cells are fractured. This may be accomplished by grinding in a Waring blender or similar type of apparatus, or lacking this, in a mortar with clean sand.

Catalase. This enzyme is much easier to destroy than peroxidase, and is not usually determined. For its detection, a 3 per cent solution of hydrogen peroxide is prepared by diluting one part of 30 per cent hydrogen peroxide with 9 parts of distilled water. It is necessary to prepare this 3 per cent solution just before use, because it will not keep. Four samples of the reconstituted material are prepared in about 10 cc of distilled water. Two of the samples are boiled for 5 min to inactivate the enzyme, and then allowed to cool to the same temperature as the unboiled samples. Controls for the reagents are prepared with 10 cc of distilled water. Three drops of 3 per cent hydrogen peroxide are now added to each test tube and the evolution of gas is noted. If this is greater in the test sample than in the controls, the test sample has not been completely inactivated. If there is no evolution of gas, some of the raw material should be examined to see if the hydrogen peroxide has lost its strength. In a positive test, there will be evolution of fine bubbles of gas which will accumulate on the surface of the liquid in the tubes and will have the appearance of a scum. If the bubbles are coarse, it probably signifies entrapped air, rather than oxygen.

Peroxidase. A 1 per cent solution of guaiacol U. S. P. in 95 per cent ethyl alcohol is used (1 gram of guaiacol to 100 cc of ethyl alcohol; the alcohol should not be denatured, and methyl alcohol is not considered satisfactory). A 1 per cent solution of benzidine is prepared by dissolving 1 gram of the compound in 100 cc of ethyl alcohol. The samples and control are prepared as in the test for catalase. To each test tube is added 1 drop of 3 per cent hydrogen peroxide (prepared as described under catalase), the solution in the tubes shaken and then 3 drops of guaiacol solution added. The reagent is well mixed with the sample, and allowed to stand. A pink or reddish color indicates the presence of peroxidase. In British practice, if the color does not appear within two minutes, the test is considered negative. In American practice, the sample is allowed

to stand for 15 min, and if no coloration appears within this time, the test is negative. If the boiled control is colored to the same extent as the test sample, it can be assumed that the color is due to factors other than peroxidase.

To test the strength and purity of the benzidine and guaiacol solutions, a test on the unblanched sample should be made, following the same procedure as given above.

Benzidine is used in the same manner as guaiacol, but a blue color is obtained in the presence of peroxidase. As previously pointed out, however, benzidine is not as specific as guaiacol, and a positive test may be obtained even in the absence of peroxidase.

It is better not to handle the sample with the fingers, but rather with a pair of forceps. Some experimenters state that the mere handling of the product will give a positive test for peroxidase even though this enzyme may be absent.

Davis[1] has devised a semiquantitative test for peroxidase which may be used in routine examinations. The test is based upon the time required for a standard solution of iodine to oxidize a standard amount of sodium thiosulfate, the end point being indicated by the appearance of a blue-black starch-iodine color. The speed of the reaction is determined by reducing substances present in the tissues being tested and those that have been added, and by the quantity of peroxidase. Ascorbic acid is the most important reducing substance found in the tissues being examined, and a decrease in the quantity of ascorbic acid will decrease the reaction time. This would introduce an error in the determination, and therefore Davis adds a relatively large quantity of sodium thiosulfate to offset changes in the amounts of ascorbic acid present.

Briefly, the test is carried out as follows: Twenty-five grams of fresh material (or 2 grams of dehydrated) are finely divided in a Waring Blender, or a similar type of mixer, with 140 cc of a buffer solution. The buffer consists of 20 cc of 2 per cent soluble starch, 10 cc of $0.1N$ sodium thiosulfate, 4.5 grams of potassium iodide, and sufficient $0.2N$ acetate buffer to make 1 liter. This mixture will keep for 24 hours. The acetate buffer is prepared by dissolving 29.7 grams of sodium acetate and 10.9 grams of acetic acid in 2 liters of distilled water. This should have a pH of 4.7. The sample, prepared as above,

[1] Davis, W. B., "Quantitative Field Test for Estimation of Peroxidase," *Ind. Eng. Chem., Anal. Ed.*, 14, 952 (1942).

is filtered through cheesecloth or a cotton towel and squeezed as dry as possible by hand. The filtrate is made up to 200 cc by the addition of buffer. To a 50-cc aliquot of the filtrate is added 1 cc of a 0.9 per cent solution of hydrogen peroxide (prepared from 30 per cent hydrogen peroxide as explained under the qualitative test for catalase) from a quick-flowing pipette. When the pipette is half empty, a stop-watch is started and the time required for the first appearance of color change noted. The reciprocal of this time is taken as the enzyme activity. Davis points out that the test is not supposed to fix the proper amount of blanching, "but only to show when that amount has been obtained." The value of the test may perhaps be improved if a blank is run the same time as the sample, although Davis does not suggest this.

Table 72. Application of Field Test for Peroxidase Destruction in Vegetables (*Davis*)

Vegetable	Blanched (min)	Time to Reach End Point[a] Before Drying (sec)	(sec)	After Drying (sec)	(sec)
Purple cabbage	0	4.0	4.5	6.5	7.5
	1	29	25	62	97
	2	68	72	145	173
	5	480	655	290	300
Mustard greens	0	7.0	7.5	18	20
	0.5	209	255	285	306
	1	330	382	335	352
	4	550	655	452	453
Beets	0	33	48	67	62
	10	215	215	255	250
	20	265	315	295	322
Carrots	0	225	230	223	217
	1	230		222	235
	6	180	180	216	251

[a]Duplicate samples run

Table 72 shows some results obtained by this test. In some instances the reaction time for dehydrated material is less than for the freshly blanched. This is thought to be due to the loss of ascorbic acid or to regeneration of the enzyme.

Balls [2] and Balls and Hale [3] have devised a strictly quantitative test for both catalase and peroxidase in which both these enzymes are

[2] Balls, A. K., "Estimation of Catalase in Agricultural Products," *J. Assoc. Off. Agr. Chem.*, **15**, 483 (1932).

[3] Balls, A. K., and Hale, W. S., "Determination of Peroxidase in Agricultural Products," *ibid.*, **16**, 445 (1933).

expressed as definite units. Such tests would be too involved for ordinary plant routine determinations, but are of value in fundamental work. The approximate peroxidase content of some plant materials, as found by Balls and Hale, is given in Table 73.

Table 73. Approximate Peroxidase Content of Some Plant Products
(Balls and Hale)

	Peroxidase Units per Kilo		Peroxidase Units per Kilo
Malt sprouts*	550	Beets	11
Horseradish	403	Wheat*	10
Turnips	110	Barley	9
White potatoes	36	Barley with hulls	3
Sweet potatoes	30	Oats	3
Radishes	30	Onions	3
Rye	14	Soybeans	2

*The grains were dry, the vegetables not dried. Except radishes and onions, the plants had been stored through the winter.

Vitamins. With the exception of ascorbic acid, vitamins are not usually determined as a routine procedure in dehydrated vegetables. If the dehydrator should consider their determination of importance, the following methods are believed to yield the most reliable results:

Vitamin A (determined as carotene). Moore, L. A., "Determination of Carotene in Plant Material," *Ind. Eng. Chem. Anal. Ed.*, 12, 726 (1940).

Wall, M. E., and Kelley, E. G., "Determination of Pure Carotene in Plant Tissue," *ibid.*, 15, 19 (1943).

Thiamin and Riboflavin. Conner, R. T., and Straub, J., "Combined Determination of Thiamin (B_1) and Riboflavin (B_2) in Food Products," *Ind. Eng. Chem., Anal. Ed.*, 13, 369 (1941). (Some analysts do not consider this method satisfactory for meats.)

Ascorbic Acid. Loeffler, H. J., and Ponting, J. D., "Ascorbic Acid Determination in Fruits and Vegetables, Fresh, Frozen, or Dehydrated," *Ind. Eng. Chem., Anal. Ed.*, 14, 846 (1942).

Nicotinic Acid (Niacin). Green, R. D., Black, A., and Howland, F. O., "Microbiological and Chemical Assay of Nicotinic Acid in B Complex," *ibid.*, 15, 77 (1943).

Bacteria in Air of the Plant. This is not a routine procedure. The method given below, although not quantitative and not in accordance with standard recognized procedures, will give an indication of the number of organisms in the air about the plant. Nutrient agar is poured into sterile Petri dishes and when the agar has cooled and solidified, the dishes are ready for use. A dish containing the agar is exposed to the air for exactly one minute, by merely taking off the lid. The cover is then replaced and the plate is then incubated

at 37° C for 48 hrs. The number of organisms (mold and bacteria) per liter of air may then be determined from the formula:

$$\frac{10 \times \text{No. colonies on plate}}{\text{area of plate in sq cm}} = \text{No. of organisms per liter of air.}$$

To simplify the calculations, the result obtained multiplied by .0353 will give the number of organisms per cubic foot. Areas of standard Petri dishes of different diameters are given in Table 74.

Table 74. Area of Petri Dishes of Different Diameters

Diameter (mm)	Approx. Area (sq cm)	Diameter (mm)	Approx. Area (sq cm)
86	58	93	68
87	59.5	94	69.5
88	61	95	71
89	62.3	96	72.3
90	63.5	97	74
91	65	98	75.3
92	66.5	99	77
		100	78.5

Dried Eggs

Moisture is determined according to the standard methods of the Official Agricultural Chemists.

Solubility. Stuart, Grewe and Dicks [4] have developed two fairly rapid methods for determining the solubility of spray-dried whole egg powder. The methods are also sensitive enough to detect adulteration of egg powder of good solubility with small amounts of insoluble egg powder.

In method No. 1, 1.5 grams of the egg powder are added to 50 cc of distilled water (or 3.0 grams to 100 cc of water) at 70 to 75° F in a ground-glass-stoppered graduate. The contents are vigorously shaken and the graduate allowed to stand for 30 min at room temperature. The graduate is then shaken about 50 times and the contents filtered through a fluted filter paper (Whatman No. 12 is suitable) and 5 cc of the first 10 cc of filtrate transferred by means of a pipette to a 15-cc tapered centrifuge tube graduated in 0.1-cc divisions. Five cc of 0.1*M* sodium acetate buffer * are added, followed by

[4] Stuart, L. S., Grewe, E., and Dicks, E. E., "Solubility of Spray-Dried Whole Egg Powder," *U. S. Egg and Poultry Mag.*, 48, 483 (1942).

* The acetate buffer described under the Davis Test for peroxidase (p. 264) may be used.

distilled water to bring the final volume to 15 cc. The tube is placed in a boiling water bath for 2 min, cooled and then centrifuged at 2500 rpm for five minutes. The sediment is read from the tube and recorded as "Centrifuged Heat Coagulable Solubility Index."

In Method No. 2, the egg powder is treated with water in the same manner as in Method No. 1. The filtrate is transferred to a 15-cc centrifuge tube, as described above, and 10 cc of Esbach's reagent added.† The tube is plugged and the contents mixed by inverting two or three times and then allowed to stand at room temperature. At the end of 18 hrs, the volume of settled precipitate is noted, and the reading recorded as "Esbach's Sedimentation Solubility Index." The relationship between the two methods and to total soluble nitrogen and crude albumen nitrogen is shown in Table 75.

Table 75. Relation of "Solubility Index" to Total Soluble Nitrogen and Crude Albumen Nitrogen Values[a]
(Stuart, Grewe and Dicks)

Sample No.	Esbach's Sedimentation solubility index	Centrifuged heat-coagulable solubility index	Total sol. nitrogen per gram dry egg (mg)	Crude albumen nitrogen per gram dry egg (mg)
1	4.10	1.5	34	23
2	4.00	1.4	33	22
3	3.85	1.2	31	21
4	3.80	1.1	29	20
5	3.70	1.0	27	19
6	3.65	0.9	25	18
7	3.50	0.7	25	17
8	3.40	0.5	24	16
9	1.35	0.3	19	14
10	0.40	0.1	8	5

[a] Determined by Official and Tentative Methods of Analyses of the Association of Official Agricultural Chemists.

Bacteria are determined according to Standard Methods for the Examination of Dairy Products, 8th Ed. (1941) published by the American Public Health Association, New York City.

It is believed that viable organisms in whole dried eggs should not exceed 300,000 per gram.

Dry Milk

Moisture, protein, fat and total sugars are determined according to the "Official and Tentative Methods of Analyses of the Association of Official Agricultural Chemists."

† Prepared by dissolving 1 gram of picric acid and 2 grams of citric acid in 100 cc of distilled water.

Bacterial examination is conducted according to Standard Methods for the Examination of Dairy Products.

Whipping Quality of Dried Egg Albumen: The practical value of egg albumen is determined by measuring its whipping quality. One and one-half ounces of fermented egg albumen are mixed with 15 oz of water and allowed to stand with occasional stirring for 3 hrs. The mixture is then poured into a 10-quart bowl of a Hobart mixer and beaten for 1½ minutes at medium speed and for 1½ minutes at high speed. If unfermented albumen is being examined, one oz is added to 7 oz of water and allowed to stand for 3 hrs. The time of beating is 2 minutes at second speed and 4 minutes at high speed.

The meringue obtained from the above procedure is leveled and the depth measured with a ruler. A whip of 6½ inches or more is considered "fancy"; below 6 inches is a poorer grade. A good meringue will break clean and has a firm structure. If the meringue crackles, it will not hold up.

In place of measuring the foam, the "weepage" may be recorded. To carry out this test, a weighed amount of the foam is placed in a funnel placed over a graduated cylinder and the time required for the first drop to appear is noted. The volume of liquid obtained (weepage) at different intervals of time up to one hour is also recorded.

Reconstitution of Dehydrated Vegetables

Dehydrators of vegetables put their recommended procedures for reconstitution on the label of the container. Most of these directions call for reconstitution in less than an hour, but the longer the vegetables are soaked the better the product. It will require longer for reconstitution with hard water than with soft water, and the addition of common salt will also increase the time for reconstituting. The effect of chlorine in chlorinated waters would have no appreciable effect upon the flavor of the product.

Although considerable work has been accomplished in this country and in England on the reconstitution of vegetables, and the different factors affecting satisfactory reconstitution, nearly all of it remains unpublished. Kröner and Lamel,[5] working in Ger-

[5] Kröner, W., and Lamel, H., "Ueber das Quellungsvermögen von Trockenspeisekartoffeln in Wasser," *Z. f. Spiritusind.*, **63**, No. 48, 259 (1940).

many, have studied the reconstitution of dehydrated potato slices. They concluded that:

(1) The rapidity of water absorption of the dried slices was proportionally small. The maximum increase in volume was reached after 8 to 10 hours; that of weight after 12 to 14 hrs.

(2) The magnitude of water absorption varied greatly with different products found in commerce, varying between 100 and 280 per cent of the weight of the slice.

(3) Salt solutions and tap water retarded reconstitution.

(4) Rapidity of reconstitution in boiling water was 12 to 15 times greater than in water at room temperature. Slices not soaked before cooking, however, gave pieces non-uniform in character. Soaking is therefore necessary, and the soaking time must be from 1 to 2 hrs.

(5) The ability of potato slices to reconstitute was greatly influenced by the process of manufacture.

(6) Potatoes with low starch content reconstituted better than those with high starch content.

(7) Steam-blanched slices reconstituted better than water-blanched slices.

(8) Time of blanching had relatively little influence on reconstitution.

(9) Slices dehydrated at relatively high temperatures for a short time reconstituted better than those dried at lower temperatures for a longer time.

The following procedures may be used in reconstituting the more common vegetables, but the technique described may not necessarily be the most ideal.

Baked Beans. About 2 parts of water are added to one part of beans and allowed to stand for 1½ hrs. The dehydrated beans are then heated in a saucepan.

Beets. Best results are obtained by soaking the beets overnight in a refrigerator. A minimum amount of water should be used, to discourage "bleeding." Where overnight soaking is impossible, the vegetable may be soaked in cool water for 30 min and then boiled until tender. Sufficient water should be used to only cover the beets.

Cabbage. If the cabbage is to be used as a slaw, the material is covered with cold water and allowed to stand in a refrigerator

for about 2 hours, taking care that the product does not freeze. The addition of ice to the water will aid in rendering the product more crisp, but the reconstituted product will not have crispness of the fresh vegetable. If it is to be served cooked, the cabbage (without previous soaking) is dropped into boiling water and boiling continued until sufficiently tender. This generally requires from 15 to 25 min.

Carrots. These are soaked for 30 min in cold water, using only enough water to cover. The carrots are then boiled for 30 min; longer boiling will yield a more tender product.

Corn is reconstituted by soaking 30 min in cool water using about 5 or 6 times as much water as corn. The soaked product is then boiled for about 30 min, or until tender.

Chard is dropped into rapidly boiling water and cooked for 15 to 20 min. Only sufficient water to cover is used.

Kale is reconstituted in the same manner as chard.

Lima beans are prepared by soaking for 2 hours in cool water using about 4 times as much water as beans. They are then boiled for about 45 min.

Mustard Greens are treated in the same manner as chard.

Onions. If the onions are to be consumed raw, the material is covered with cold water and allowed to stand in the refrigerator for about 2 hrs. If they are to be eaten as boiled onions, they are soaked in cool water for 30 min and boiled until tender.

Potatoes, sweet. Best results are obtained by soaking 1 hr in cool water and then boiling for 30 min. Soaking may be shortened to 30 min but the product will be inferior to that obtained by soaking 1 hr. About 1½ times as much water as potatoes is used.

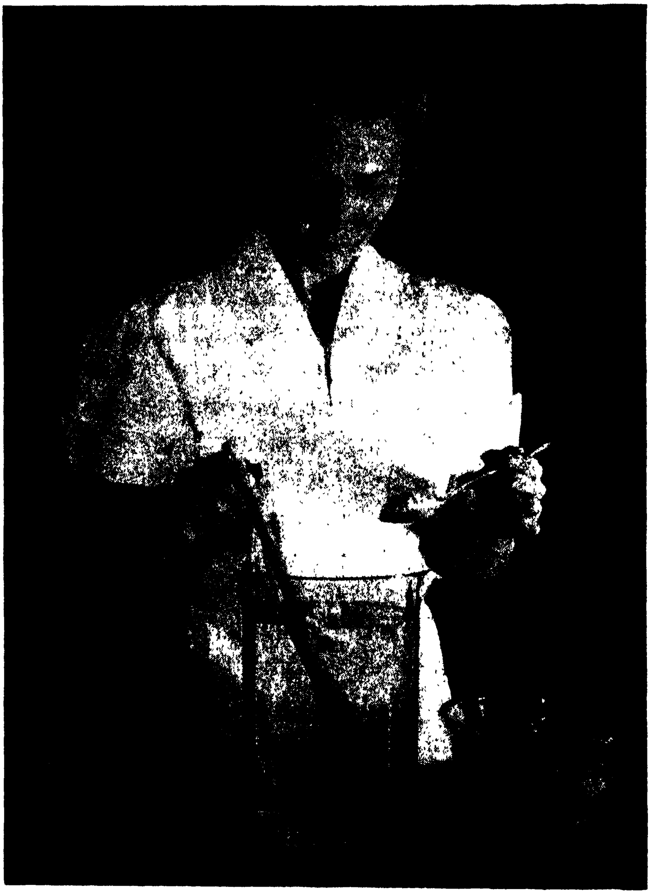
Potatoes, white. If the product is riced, the material is dropped into boiling water and cooked, with constant stirring, for about 15 min. The amount of water added must be carefully controlled because too much water will yield a soggy product. Slices, strips and cubes are soaked 30 min and then boiled for 30 min. From 4½ to 5 times as much water as potatoes is used.

Rutabagas. These are dropped into sufficient boiling water to cover and boiling continued for 30 min.

Snap beans are reconstituted by soaking in warm water for about 1 hr and then boiling until tender.

Spinach is dropped into rapidly boiling water and cooked for 10 min. Only sufficient water to cover should be used.

Although every effort is made to maintain the vitamin content of vegetables during preparation and dehydration, little has been



Courtesy U. S. Dept. of Agriculture. (Photograph by Forsythe)

FIG. 63. Reconstitution of a vegetable soup. The powder is mixed with water in the correct proportion to obtain one gallon of finished soup.

done to learn the methods for best preserving the nutritive value during the process of reconstitution. There are no reliable published data to indicate losses suffered during preparation for consumption, or the best methods of reconstituting.

Table 76 gives the quantity of reconstituted vegetables obtained

Table 76. Approximate Amount of Reconstituted Vegetables Obtained from One Pound of Dehydrated.

1 lb dehydrated beets yields about	6.7 lbs reconstituted
1 lb dehydrated cabbage yields about	10.7
1 lb dehydrated carrots yields about	4.9
1 lb dehydrated chard yields about	5.5
1 lb dehydrated kale yields about	5.7
1 lb dehydrated mustard greens yields about	5.8
1 lb dehydrated onions yields about	7.0
1 lb dehydrated potatoes, sweet, yields about	2.6
1 lb dehydrated potatoes, white, yields about	5.8
1 lb dehydrated rutabagas, yields about	2.3
1 lb dehydrated spinach, yields about	7.0

Table 77. Approximate Quantity of Dehydrated Vegetables Required to Give One Pound of Reconstituted
(*Chace*)

Vegetable	Amount required to yield 1 lb of reconstituted (oz)	Vegetable	Amount required to yield 1 lb of reconstituted (oz)
Beets	2.4	Onions	2.3
Cabbage	1.5	Sweet potatoes	6.2
Carrots	3.3	White potatoes	2.7
Chard	2.9	Spinach	2.3
Kale	2.8	Rutabagas	5.0
Mustard greens	2.8		

from one pound of dehydrated, and in Table 77 is indicated the approximate quantity of dehydrated vegetables to yield one pound of reconstituted.

Reconstitution of Dried Eggs

Dried eggs are used extensively by bakers, the military and confectioners, and to a limited extent by hospitals, hotels and restaurants. With the exception of certain civilians of the United Nations, they are not used by the housewife.

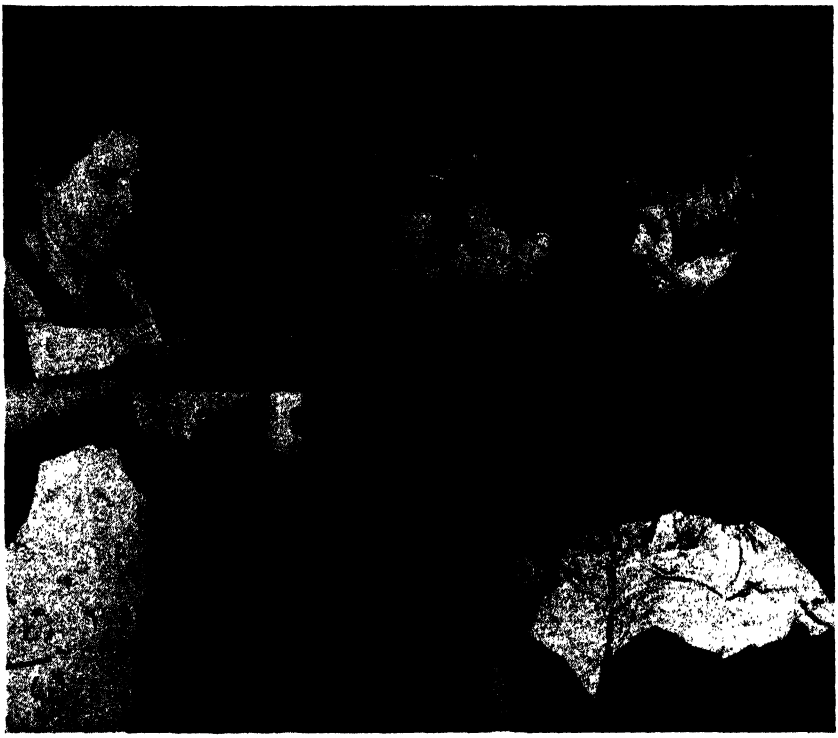
Egg products are reconstituted as follows, in order to get the equivalent of fresh eggs:

Table 78. Approximate Number of Grams of Whole Egg Powder and Water to Yield the Equivalent of Whole Liquid Eggs

Dry Egg Powder (grm)	Water (cc)	Equivalent number of Whole Eggs
11.6	34.8	1
23.2	69.6	2
34.8	104.4	3
46.4	139.2	4
58.0	174.0	5
69.6	208.8	6
81.2	243.6	7
92.8	278.4	8
104.4	313.2	9
116.0	348.0	10
127.6	382.8	11
139.2	417.6	12

Dried Whole Egg. One part of whole egg is mixed with 3 parts of water by weight. The mixture is allowed to stand with occasional stirring until liquid-egg consistency is obtained. This may require 15 to 30 min.

Dried Yolk. One part of dried yolk is mixed with 2 or 3 parts of water by weight. The mixture is allowed to stand for one hour with occasional stirring.



Courtesy British Ministry of Food

FIG. 64. Children in London's East End get drinks of milk made from American dried milk.

Dried Albumen. One part of dried albumen is mixed with 10 parts of water by weight and allowed to stand for 3 hrs with occasional stirring.

Reconstitution of Dry Milk

Dry whole milk, dry buttermilk and dry skim milk are used by bakers, ice-cream manufacturers, confectioners, the military, and

Table 79. Production of Dried Fruits (in short tons)*

Year	Dried Apples	Pears	Prunes[a]	Raisins[b]	Peaches	Figs	Apricots	Berries[c]
1930	26,300	4,500	285,200	192,000	26,100	15,100	23,800	...
1931	22,500	4,400	242,400	169,000	21,500	9,500	37,400	500
1932	23,550	5,500	194,500	262,000	22,200	14,300	35,300	250
1933	25,800	7,000	205,500	195,000	23,400	17,200	37,500	350
1934	19,500	4,900	201,100	171,000	25,800	18,700	16,800	300
1935	25,800	6,100	297,300	203,000	19,500	18,700	25,800	300
1936	20,700	8,100	184,300	182,000	26,400	15,000	32,200	400
1937	25,500	3,500	255,700	247,000	23,000	23,600	34,400	250
1938	20,000	6,500	238,300	290,000	22,000	20,600	21,500	350
1939	25,400[c]	8,100	213,400	245,000	24,300	21,500	41,000	250
1940	13,000[c]	3,100	177,700	171,000	24,400	24,100	11,350[c]	150
1941	18,000[c]	3,600	188,400	209,000	14,300[c]	24,600[d]	19,700[c]	45

* From data compiled by S. W. Shear, Giannini Foundation of Agr. Econ. Coll. Agr., Univ. Calif. Data on dried Berries from *Western Canner and Packer Yearbook*, **34**, 240C, (1942).
[a] Does not include small amounts produced in Idaho.
[b] Excludes dried grapes other than raisin varieties.
[c] Preliminary estimates.
[d] Merchantable pack.
[e] In the Pacific Northwest.

to a limited extent by hospitals. Skim-milk powder has found the greatest use because of the uncertain keeping qualities of whole-milk powder.

To prepare a fluid milk from the dry product, the powder is sprinkled slowly upon the surface of the proper amount of warm water kept in constant agitation. A *fluid skim milk* or *buttermilk* is made by adding 10 lbs of the powder to about 12 gals of water.

Table 80. Production of Dried Milks in the United States (*Bur. Agr. Econ. and Agr. Marketing Service, U. S. Dept. Agr.*)

Product	1934 (lbs)	1936 (lbs)	1938 (lbs)	1940 (lbs)
Dry skim milk	294,935,000	349,550,000	449,039,000	481,743,000
Dry whole milk	15,869,000	18,180,000	21,496,000	29,409,000
Dry cream	65,000	178,000	40,000	54,000
Dry buttermilk	53,636,000	50,781,000	63,910,000	67,931,000
Malted milk	13,569,000	18,495,000	15,394,000	20,021,000

Fluid whole milk is prepared by adding 14.5 lbs of whole dry-milk powder to about 12 gals of water. For household use, the following proportions may be utilized:

1 cup dry skim milk (or dry buttermilk) to one quart of water;
1 rounded cup dry whole milk to one quart of water;
¼ cup dry skim milk (or dry buttermilk) to 1 cup water;
slightly more than ¼ cup dry whole milk to one cup water.

Reconstitution of Dried Beef Serum

This product was developed primarily as a substitute for egg albumen. However, it will not form as stable a foam as egg albumen and its use is therefore limited. To obtain the equivalent of the whites of one dozen fresh eggs, 36 g of the dried serum are added to 192 cc of water; or 3 g added to 16 cc of water will give the equivalent of the liquid white of one egg.

Very little success has been attained in using dried beef serum in meringues and whips in the same manner as egg albumen. The

Table 81. Estimated Production of Dehydrated Vegetables*

Year	Production
1940	15,000,000
1941	40,000,000
1942	100,000,000

* These are only estimates. There are no reliable data regarding the production of dehydrated vegetables during the past few years. Present production is considered a military secret.

Table 82. Approximate Space Occupied by 2000 Pounds of Certain Fresh Commodities and these same Commodities when Dehydrated or Canned.

Commodity	Fresh (cu ft)	Dehydrated[b] (cu ft)	Canned (cu ft)
Apples	51.9	3.9	83.3
Apricots	51.8	7.0	51.8
Beans			
Lima	78.1	6.1	28.4
Snap	83.4	16.4	74.4
Beets	60.0	7.8	66.6
Cabbage	75.2	15.1	....
Carrots	49.8	9.1	66.6
Corn	71.6	7.5	47.5 (packed Maryland style) 32.1 (cream style pack) 40.2 (vac. pack whole kernel)
Eggs	88.9	13.7	....
Figs	60.0	24.2	83.5
Meat	52.0*	35.2	....
Milk	30.9	8.1	26.6**
Onions	43.9[a]	7.5	....
Peaches	51.8	5.4	51.8
Pears	50.0	5.3	48.3
Peas	83.4	6.0	28.4
Potatoes, sweet	45.3	10.8	....
Potatoes, white	41.5	14.7	52.5
Prunes	44.6	34.6	83.4
Raisins	52.3	46.7	....
Rutabagas	44.4	25.0	....
Spinach	138.0	9.7	32.8

* Pork, dressed Wiltshire sides.
** Evaporated milk.
[a] Early onions only.
[b] volume occupied by container not included.

reasons for this are that the foam obtained is too unstable, and that uncooked preparations of beef serum have a slight animal taste. In baked goods, however, this taste cannot be detected. Cakes made

with dried beef serum appear to keep moist for a longer period than those prepared with either fresh or dried egg albumen.

Dried beef serum cannot be used as a substitute for whole dried eggs; to duplicate whole dried eggs, one part of the dried serum is mixed with 3 parts of dried egg yolk.

Reconstitution of Meat

All the dehydrated meat now produced is in the form of small grains (not powder) and its use is limited to certain types of soups, and the preparation of meat balls and meat loaves. To reconstitute, one pound of the dehydrated meat is added to 1 qt 6 oz of water and allowed to simmer gently for 50 min. After reconstitution in this manner it should not be allowed to stand for any length of time because there may be some danger of growth of food-poisoning organisms, should any survive the 50-min treatment with hot water.

Suggested Readings

Cruess, W. V., "Commercial Fruits and Vegetable Products," 2nd Ed., McGraw-Hill Book Co., New York, 1938.

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Ritchell, E. C., Piret, E. L., and Mann, C. A., "Laboratory Apparatus for Controlled Experimental Drying of Foods," *Proc. Inst. Food Technologists*, p. 23 (1941)

Cruess, W. V., and Joslyn, M. A., "Significance of Enzyme Reaction to Dehydration of Vegetables," *ibid.*, p. 99, (1942).

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"Official and Tentative Methods of Analyses of the Association of Official Agricultural Chemists," Washington, D. C.

Anon., "General Information Sheet on Dehydration of Vegetables," Dehydration Committee, *U. S. Dept. Agr., Bur. Chem. & Eng.* ACE-163 (1942).

Balls, A. K., "The Fate of Enzymes in Processed Foods," *Fruit Products J.*, 22, 36 (1942).

"Standard Methods for the Examination of Dairy Products," American Public Health Association, New York, N. Y.

Terre, W. L., "The Control Laboratory in the Egg Industry," *Am. Egg Poultry Rev.*, 3, No. 13, 632 (Dec., 1942).

Appendix

Glossary of Terms

Aerobic: as applied to bacteriology, signifies a bacterium that requires an atmosphere of oxygen for its growth.

Anaerobic: as applied to bacteriology, signifies a bacterium that will grow in an oxygen-free atmosphere. It derives its necessary oxygen from the media upon which it grows.

Ascorbic acid: same as vitamin C. Deficiency of this vitamin causes scurvy, and fragility of the capillary blood vessels, with resulting hemorrhages throughout the body.

Banana flour: a product made from unripe bananas, or those varieties of fruit high in starch.

Banana powder: a product prepared from ripe bananas.

Blanching: treatment of a food material with steam or hot water under atmospheric pressure.

Bloaters: Puffy prunes containing air pockets usually resulting from fermentation.

Blood plates: pale discs found in normal blood.

Boiler Horsepower: the measure of the capacity of a boiler. The evaporation of 34½ pounds of water per hour from and at 212° F.

Brix: the per cent of soluble solids (usually assumed to be sugars) in a liquid. Brix degrees is measured with a hydrometer graduated in the Brix scale.

Btu: British Thermal Unit. Heat required to raise the temperature of one pound of water from 60 to 61° F.

Calorie: a small calorie is the quantity of heat required to raise the temperature of one gram of water from 4 to 5° C. A large (kilogram) Calorie is 1000 times a small calorie.

Carotene: Provitamin A. A lipochrome occurring in green vegetables and carrots and other foodstuffs. In the normal organism, carotene is changed to vitamin A.

Chocolates: a term applied to prunes that have been dried to a chocolate brown color.

'Cot: California contraction of "apricot."

Crenation: Shriveling of red blood corpuscles giving them a mulberry appearance.

Cyptoplasm: A viscid colloidal material that forms the physical basis of all life of the cell body, except the nucleus.

Cups: Halves of apricots or peaches from which the pits have been removed.

Dehydrater: Equipment used for dehydration.

Dehydrator: A person engaged in the art of dehydration.

Dehydration: Drying by artificial heat under carefully controlled conditions of temperature, humidity and air-flow.

Desiccation: same as dehydration.

Dew Point: that temperature at which a given mixture of air and water vapor is saturated with water vapor. When the outside temperature reaches the dew point, dew will form in summer.

Dry-bulb temperature: degrees of heat registered by an ordinary thermometer.

Dryer: same as dehydrater.

Dried: term applied to all products from which water has been substantially removed, such water being removed under conditions not so carefully controlled as stated under "dehydration."

Effluent: sewage flowing from a plant, dwelling or treatment plant.

Erythrocytes: red blood corpuscles.

Evaporation: Drying under conditions of temperature, humidity and air-flow not as carefully controlled as under dehydration.

Evaporator: Any equipment used to dispel water, usually under a vacuum. Sometimes considered synonymous with "kiln."

Frogs: same as bloaters.

Frog bellies: same as bloaters and frogs.

Horsepower: rate of work. Unit of horsepower is 33,000 foot pounds per minute, or 550 foot pounds per second. Expressed in heat units, one horsepower is 42,416 Btu per min; in electrical units, 746 watts.

Humidity, absolute: actual weight of moisture per unit weight of dry air.

Humidity, relative: weight of water vapor (expressed as per cent) contained in a given volume of air, divided by the weight which would be contained in the same volume of saturated air at the same temperature.

Hydrogen cyanide: an intensely poisonous, colorless gas or liquid with a characteristic almond-like odor. It boils at 26° C and is used for fumigation.

Kiln: as applied to drying of foods, a structure with a slatted floor beneath which is located a heating unit. Air is circulated by natural draft.

Laking: as applied to blood chemistry, the destruction of the red corpuscles rendering the blood transparent.

Latent heat: Heat required to change a substance from a solid to a liquid at its melting point, or from a liquid to a gas at its boiling point.

Leukocyte: a white blood corpuscle.

Parenchyma: tissue composed of thin-walled cells of equal diameters.

Plasmolysis: escape of soluble substances from the cell.

Riboflavin: same as vitamin B_2; deficiency leads to sore lips with fissuring at angles, and greasy accumulations at angles of the nose.

Saprophyte: a microörganism that lives on dead or decaying animals or plants.

Scalding: British term for blanching.

Sewage: waste matter from a dwelling, plant or groups of dwellings and/or plants.

Sewerage: system used to convey sewage.

Slabs: dried peaches or apricots that have flattened out and stuck together during drying and no longer retain their cup shape.

Specific heat: the number of calories required to raise the temperature of one gram of a substance one degree centigrade.

Sugaring: term applied to prunes or other dried fruits having a white coating on the surface.

Syndrome: a complexus of symptoms.

Thiamin: same as vitamin B_1. Deficiency causes inflammation of several nerves (polyneuritis), beriberi, increase in size of the heart, slowing of its rate, and edema.

Vitamins: a group of accessory organic substances, in addition to proteins, fats, carbohydrates and salts, essential for normal nutrition.

Vitamin A: found in certain animal tissue, but not in plant tissue. Deficiency in the diet results in impaired vision (night blindness), xerophthalmia (a dry and thickened condition of the conjunctiva of the eyes), injury to the linings of the cavities of the body, dryness and scaliness of the skin.

Vitamin B_1: see Thiamin.

Vitamin B_2: see Riboflavin.

Vitamin C: see Ascorbic acid.

Vitamin G: same as vitamin B_2.

Wet-bulb depression: difference in reading between wet- and dry-bulb temperatures.

Wet-bulb temperature: temperature obtained from a thermometer whose bulb is kept wet by means of a wick dipping into a container of water.

Vapor pressure: the pressure at which a liquid and its vapor are in equilibrium at a definite temperature.

Xylem: that part of vascular bundles of plant tissue lying next to the pith.

Partial List of Patents Pertaining to Dehydration of Foods

Dry Milk

British Pat. 524,371. Aug. 5, 1940. Dried Milk Products. K. W. E. Schmitz and L. E. Haub (nee Schmitz) and W. Schmitz (trading as W. Schmitz-Scholl).

U. S. Pat. 2,213,283. Sept. 3, 1941. Dried Milk. N. M. Kronberg, to Svenska Mjölkprodukter Aktiebolag.

U. S. Pat. 1,705,332. Mar. 12, 1929. Process of Making Food Product (Malted Milk). S. A. McDougall, to Dextora Co.

U. S. Pat. 1,738,275. Dec. 3, 1929. Cold Milk-Dehydration Process. E. Baker. 51% to A. A. Haskell and P. C. Holland.

U. S. Pat. 1,841,842. Jan. 19, 1932. Food Product. S. Musher.

U. S. Pat. 1,905,203. April 25, 1933. Process and Apparatus for Producing Dehydrated Products. J. A. Burner.

U. S. Pat. 1,966,513. July 17, 1934. Free Flowing Powdered Milk. H. V. Moss and T. U. Wheelock, to Swann Research Corp.

U. S. Pat. 2,116,931. May 10, 1938. Process for Recovery of Lactose from Whey. A. Leviton, to the Secretary of Agriculture of the United States.

U. S. Pat. 2,129,222. Sept. 6, 1938. Process for the Recovery of a Soluble Protein Powder from Whey. A. Leviton, to the Secretary of Agriculture of the United States.

U. S. Pat. 2,132,897. Oct. 11, 1939. Vacuum Drying of Vegetables, Berries, Fish. Eggs, Milk, etc. J. G. W. Gentele.

U. S. Pat. 2,143,256. Jan. 10, 1939. Desiccating Materials such as Milk. H. I. Andrews.

U. S. Pat. 2,143,019. Jan. 10, 1939. Apparatus for Two Stage Drying of Materials such as Whey on Heated Drums. C. O. Lavett, to Buffalo Foundry and Machine Co.

U. S. Pat. 2,163,331. June 20, 1939. Method of Drying Milk Whey. G. C. Supplee, to Borden Co.

U. S. Pat. U. S. 2,211,153. Aug. 13, 1941. Dried Milk. N. M. Kronberg, to Svenska Mjölkprodukter Aktiebolag.

U. S. Pat. 2,217,547. Oct. 8, 1941. Dehydrating Liquid Products such as Milk. J. M. Hall.

Can. 391,254. Sept. 10, 1940. Dried Milk. C. H. Parsons, to Industrial Patents Corp.

Fr. 833,236. Oct. 17, 1938. Milk Powder. P. L. Tival (inventor) and M. Lauriat (née Labattut).

Brit. 494,847. Nov. 2, 1938. Process for Producing Powders from Milk, etc. A. T. Früs-Andersen.

Fr. 828,264. May 13, 1938. Apparatus for Drying Milk by Pulverization onto Drums. Escher Wyss Machinenfabriken. A-G.

U. S. Pat. 2,287,795. June 30, 1942. Evaporating Moisture from Liquid Products such as Milk. J. M. Hall, to Drying and Concentrating Co.

Dried Eggs

U. S. Pat. 2,182,209. Dec. 5, 1939. Egg Product. R. C. Newton and L. D. Mink, to Industrial Patents Corp.

U. S. Pat. 2,168,926. Aug. 8, 1939. Egg White Process. V. D. Littlefield.

U. S. Pat. 2,166,070. July 11, 1939. Dried Egg White Product Suitable for use in Food. V. D. Littlefield.

U. S. Pat. 2,151,760. Mar. 28, 1939. Process of Treating Egg Material. B. R. Harris.

U. S. Pat. 2,110,613. Mar. 8, 1938. Process for Reducing Foam of Fermented Egg White to Liquid Albumen and Thinning Fresh Egg Whites. T. L. Swenson, for free use of the Public.

U. S. Pat. 2,073,411. Process of Producing Thin Egg White. A. K. Balls, and T. L. Swenson, to free use of the Public.

U. S. Pat. 2,062,387. Dec. 1, 1936. Process for the Alteration of Egg White. A. K. Balls and T. L. Swenson, to free use of the Public.

U. S. Pat. 2,054,213. Sept. 15, 1936. Thinning Egg White. A. K. Balls and T. L. Swenson, to free use of the Public.

U. S. Pat. 1,951,889. Mar. 20, 1934. Method of Preparing Dried Egg Product S. Tranin.

U. S. Pat. 1,961,770. June 5, 1934. Process and Apparatus for Dehydrating Eggs. A. H. Leach (½ to Carl Ruh).

U. S. Pat. 1,996,800. April, 1935. Preparation of Egg Products. N. Fischer, to Armour and Co.

U. S. Pat. 1,996,801. Preparation of Egg Products. N. Fischer, to Armour and Co.

U. S. Pat. 2,006,799. July 2, 1935. Process of Producing Dried Egg Whites. A. K. Epstein, B. R. Harris, and M. G. Reynolds.

U. S. Pat. 1,818,212. Aug. 11, 1931. Egg White Process. A. K. Epstein, and B. R. Harris.

U. S. Pat. 1,818,213. Aug. 11, 1931. Egg White Process. A. K. Epstein, and B. R. Harris.

U. S. Pat. 1,818,214. Aug. 11, 1931. Egg White Process. A. K. Epstein, and B. R. Harris.

U. S. Pat. 1,818,215. Aug. 11, 1931. Egg White Process. A. K. Epstein, and B. R. Harris.

U. S. Pat. 2,237,087. April 1, 1941. Drying Egg Whites. V. D. Littlefield and N. C. Fischer, to Armour and Co.

U. S. Pat. 2,237,827. April 8, 1941. Treatment of Egg White. N. C. Fischer, to Armour and Co.

German 692,808. May 30, 1940. Spray Drying. Toensfeldt.

U. S. Pat. 2,301,931. Nov. 17, 1942. Egg Cleaning Machine. R. S. Davis.

U. S. Pat. 2,302,809. Nov. 24, 1942. Egg Washer. W. Stehlik assignor of 1/3 to E. Dickman and 1/3 to Max Levine.

Fruits and Vegetables *

U. S. Pat. 1,025,373. May 7, 1912. Cooking and Desiccating Potatoes. E. W. Cook.

U. S. Pat. 1,090,782. Mar. 17, 1914. Making a Dry Food from Potatoes. E. Enders.

U. S. Pat. 1,132,020. Mar. 16, 1915. Fruit Evaporator. W. M. Luther.

* From *U. S. Dept. Agr. Circ.* 619 (1942) with additions.

U. S. Pat. 1,149,914. Aug. 10, 1915. Method of Preserving Potatoes and other Vegetables. F. W. Haussermann.

U. S. Pat. 1,174,404. Mar. 7, 1916. Food Product (fruit flour) and Processing for Producing the Same. J. C. Fleming.

U. S. Pat. 1,175,318. Mar. 14, 1917. Process for Powdering Cranberries. R. N. Stewart.

U. S. Pat. 1,222,062. April 10, 1917. Food Product and Process of Making the Same. R. H. Bent, and W. C. Bent.

U. S. Pat. 1,225,212. May 8, 1917. Art of Drying Bodies. C. E. Benjamin.

U. S. Pat. 1,258,047. Mar. 5, 1918. Method of Preparing Precooked Food Products. B. Remmers, to Armour Grain Co.

U. S. Pat. 1,259,774. Mar. 19, 1918. Apparatus for Drying Tomatoes and Fruit. T. J. Peters.

U. S. Pat. 1,259,631. March 19, 1918. Method of Preparing Evaporated Vegetables. R. W. King (to Pacific Evaporator Co.).

U. S. Pat. 1,259,633. March 19, 1918. Method of Preparing Evaporated Fruits. R. W. King (to Pacific Evaporator Co.).

U. S. Pat. 1,259,634. March 19, 1918. Method of Preparing Evaporated Apples. R. W. King (to Pacific Evaporator Co.).

U. S. Pat. 1,259,635. Mar. 19, 1918. Evaporated Vegetable Product. R. W. King (to Pacific Evaporator Co.).

U. S. Pat. 1,259,636. Mar. 19, 1918. Evaporated Apples. R. W. King (to Pacific Evaporator Co.).

U. S. Pat. 1,259,637. Mar. 19, 1918. Evaporated Fruits. R. W. King (to Pacific Evaporator Co.).

U. S. Pat. 1,269,291. June 11. 1918. Fruit Slicing and Spreading Machine. W. M. Luther.

U. S. Pat. 1,272,266. July 9. 1918. Method of Preparing (Dried) Carrot Flakes. M. C. Horn.

U. S. Pat. 1,305,599. June 3, 1919. Process for Drying Various Substances. A. A. Goubert (to H. Bentz).

U. S. Pat. 1,328,397. Jan. 20, 1920. Steam Bleaching Apparatus (for use in food dryers) R. Rea and F. W. Waters.

U. S. Pat. 1,328,395. Jan. 20. 1920. Conveying and Steam and Water Bleaching Apparatus for Dehydrating Plants. R. Rea and F. W. Waters.

U. S. Pat. 1,328,396. Jan. 20, 1920. Fruit, Vegetable, and Other Food Dehydrating Furnace and Its Cooperating Apparatus. R. Rea and F. W. Waters.

U. S. Pat. 1,328,897. Jan. 27, 1920. Method of and Apparatus for Drying Material. O. D. Rice.

U. S. Pat. 1,339,032. May 4, 1920. Apparatus for Drying Food. D. Lenzi.

U. S. Pat. 1,339,092. May 4. 1920. Method of and Apparatus for Drying Fruits, Vegetables, and Other Substances. G. H. Benjamin.

U. S. Pat. 1,347,501. July 27, 1920. Arrangement for Drying Solid Liquid-Containing Bodies. J. W. A. Elling.

U. S. Pat. 1,349,908. August 17, 1920. Dehydrating Plant. L. E. Post and D. A. Riedy.

U. S. Pat. 1,351,118. August 31, 1920. Apparatus for Dehydrating Food Products (adopted to domestic use) F. M. Nichols.

U S. Pat. 1,353,167. Sept. 21, 1920. Dehydrater. W. M. Luther.

U. S. Pat. 1,361,238-9. Dec. 7, 1920. Food Product and Method of Manufacturing the Same. R. S. Fleming (to Merrell-Soule Co.).

U. S. Pat. 1,365,001. Jan. 11, 1921. Food Product and Process for Making Same. R. deD. McDill.

U. S. Pat. 1,380,815. June 7, 1921. Food Product. S. Luft.

U. S. Pat. 1,387,710. August 16, 1921. Method of Drying Vegetables and Fruits. B. S. Harrison (to Carrier Engineering Corp.).

U. S. Pat. 1,393,086. Oct. 11, 1921. Method of and Apparatus for Drying, Conditioning, and Regulating the Moisture Content of Hygroscopic Materials. W. H. Carrier (to Carrier Engineering Corp.).

U. S. Pat. 1,393,540. Oct. 11, 1921. Desiccating Food. J. F. Kelly.

U. S. Pat. 1,408,457. Mar. 7, 1922. Method of and Apparatus for Drying Materials. B. S. Harrison.

U. S. Pat. 1,413,924. Apr. 25, 1922. Dehydrating Apparatus. F. Maus. ½ to S. J. Spoelstra.

U. S. Pat. 1,414,275. Apr. 25, 1922. Method of Drying Food Products. B. S. Harrison (to Carrier Engineering Corp.).

U. S. Pat. 1,415,010. May 9, 1922. Apparatus for Drying Fruits, Vegetables and Other Substances. G. H. Benjamin.

U. S. Pat. 1,416,793. May 23, 1922. Dehydrating Apparatus. J. D. Cox.

U. S. Pat. 1,418,386. June 6, 1922. Method of and Apparatus for Dehydrating Material. F. Maus. ½ to S. J. Spoelstra.

U. S. Pat. 1,420,679. June 27, 1922. Process and Apparatus for Dehydrating. O. Q. Beckworth and O. J. Hobson. (to Anhydrous Food Products Co.).

U. S. Pat. 1,434,837. Nov. 7, 1922. Process of Treating Dried Figs. E. Newly.

U. S. Pat. 1,435,755. Nov. 14, 1922. Dehydrating Apparatus. W. Stricker (to Perfection Dehydrator Co.).

U. S. Pat. 1,442,179. Jan. 16, 1923. Drying or Desiccating Apparatus. J. Schneible.

U. S. Pat. 1,448,512. Mar. 13, 1923. Method of Dehydrating Vegetable, Animal, and Other Materials. G. H. Benjamin.

U. S. Pat. 1,472,974. Nov. 6, 1923. Method of Treating Fruit (Apricots and Peaches) to be Dried. A. Greco.

U. S. Pat. 1,496,370. June 3, 1924. Apparatus for Dehydrating. J. H. Elpass. 1/3 to M. J. Maloney.

U. S. Pat. 1,497,193. June 10, 1924. Concentrated Food Composition and Method of Making the Same. K. Niohio and K. Matsuoko.

U. S. Pat. 1,504,108. Aug. 5, 1924. Bleaching and Sweating Apparatus for Dehydrating Materials. J. H. Elpass. 1/3 to M. J. Maloney.

U. S. Pat. 1,518,537. Dec. 9, 1924. Process of Drying Fruit. C. C. Moore.

U. S. Pat. 1,523,509. Jan. 20, 1925. Drier. W. G. R. Braemer (to General Fire Extinguisher Co.).

U. S. Pat. 1,547,561. July 28, 1925. Dehydrating Apparatus. M. E. Bussler.

U. S. Pat. 1,552,210. Sept. 1, 1925. Fruit, Vegetable, Fish and Meat Dehydrating Apparatus. M. E. Bussler.

U. S. Pat. 1,594,549. Aug. 3, 1926. Method of and Apparatus for Drying and Conditioning Materials. W. A. Noel.

U. S. Pat. 1,601,966. Oct. 5, 1926. Art of Drying. H. E. Harris to The Industrial Dryer Corporation.

U. S. Pat. 1,602,830. Oct. 12, 1926. Method of and Means for Dehydrating Fruits and Vegetables. C. C. MacPherran.

U. S. Pat. 1,701,813. Feb. 12. 1929. Dehydrating Apparatus. H. S. MacKaye to Dry Fresh Process, Inc.

U. S. Pat. 1,704,912. Mar. 12, 1929. Dehydrating Apparatus. M. E. Bussler.

U. S. Pat. 1,735,397. Nov. 12, 1929. Drying Process. S. Hiller.

U. S. Pat. 1,749,485. Mar. 4, 1930. Drier. R. Kastead.

U. S. Pat. 1,750,839. Mar. 18, 1930. One-Apron Drier. F. L. Furbush to C. G. Sargent's Sons Corp.

U. S. Pat. 1,755,373. Apr. 22, 1930. Drying. O. Soderlund and T. Gram to Techno-Chemical Laboratories, Ltd., of London.

U. S. Pat. 1,766,843. June 24, 1930. Drying of Moist Material. O. Soderlund and T. Gram. to Techno-Chemical Laboratories, Ltd., of London.

U. S. Pat. 1,805,173. May 12, 1931. Dehydrater. H. M. Griffoul.

U. S. Pat. 1,813,680. July 7, 1931. Drier. F. D. Robbins

U. S. Pat. 1,813,750. July 7, 1931. Drier. A. S. Mackenzie.

U. S. Pat. 1,881,062-3. Oct. 4, 1932. Descending Tray Drier and Multiple Tray Drier. O. W. Randolph.

U. S. Pat. 1,900,974. Mar. 14, 1933. Process of Dehydrating Vegetables and the Like. W. H. Bozarth to Osborn Products Co.

U. S. Pat. 1,908,489. May 9, 1933. Food Product and Its Manufacture. J. D. Sartakoff to Sardik, Inc.

U. S. Pat. 1,926,215. Sept. 12, 1933. Machine for Dehydrating Pomace. F. C. Stoll and C. W. Jones.

U. S. Pat. 1,927,396. Sept. 19, 1933. Dehydrating Apparatus. B. G. Freund and C. W. Thomas—35 per cent to Freund, 45 per cent to Thomas and 20 per cent to N. Lyons.

U. S. Pat. 1,929,437. Oct. 10, 1933. Drying and Preserving Process for Fruits and Vegetables. A. H. McComb—50 per cent to E. R. Peacock.

U. S. Pat. 1,979,124. Oct. 30, 1934. Process for the Preparation, in Dry Powdered Form of Animal, Fish and Vegetable Matter. H. L. P. Tival.

U. S. Pat. 1,988,678. Jan. 22, 1935. Dehydrating Process. G. D. Arnold.

U. S. Pat. 1,991,222. Feb. 12, 1935. Drying Apparatus. W. L. Laib.

U. S. Pat. 1,998,384. Apr. 16, 1935. Process for Preserving Fresh Vegetables in the Raw State. J. Petitpas.

U. S. Pat. 2,000,533. May 7, 1935. Method of Producing a Food Powder. R. T. Northcutt and A. L. Johnston, Jr. to Food Concentrates, Inc.

U. S. Pat. 2,005,238. June 18, 1935. Method of Manufacturing Dried Food Products. D. D. Peebles.

U. S. Pat. 2,006,703. July 2, 1935. Paste Feed for Driers. D. J. Van Marle to Buffalo Foundry & Machine Co.

U. S. Pat. 2,011,465. Aug. 13, 1935. Process for Inhibiting the Discoloration of Fruits and Vegetables. A. K. Balls and W. S. Hale to free use of the Public.

U. S. Pat. 2,017,728. Oct. 15, 1935. Dehydration Apparatus. H. E. Oskamp.

U. S. Pat. 2,023,247. Dec. 3, 1935. Milk-Drying Process and Apparatus. W. B. Senseman to Raymond Bros.

U. S. Pat. 2,023,536. Dec. 10, 1935. Process of Drying Fruit. C. C. Moore to Vacuodri Fruit Corp.

U. S. Pat. 2,034,860. Mar. 24, 1936. Drier. D. Dalin.

U. S. Pat. 2,037,009. Apr. 14, 1936. Process of Treating Food Materials. W. W. Cowgill to Sardik, Inc.

U. S. Pat. 2,040,227, May 12, 1936. Apparatus for Drying and Heat Treating Material. F. Wernersson.

U. S. Pat. 2,041,954. May 26, 1936. Method and Apparatus for Electrical Dehydration. P. W. Prutzman to Socony Vacuum Corp.

U. S. Pat. 2,042,145. May 26, 1936. Process of Evaporating and Equipment Therefor. W. A. Darrah.

U. S. Pat. 2,050,597. Aug. 11, 1936. Dehydrater. J. M. Younger to J. M. Thorp.

U. S. Pat. 2,054,441. Sept. 15, 1936 Method and Apparatus for Drying Liquid Containing Materials. D. D. Peebles to Western Condensing Co.

U. S. Pat. 2,060,389. Nov. 10, 1936. Method and Apparatus for Drying Organic Substances. A. E. Wigelsworth.

U. S. Pat. 2,074,740. Mar. 23, 1937. Fruit Drier. F. W. Cutler and A. B. Cutler to Food Machinery Corporation.

U. S. Pat. 2,090,984. Aug. 24, 1937. Dehydrating Apparatus and Method. D. D. Peebles.

U. S. Pat. 2,092,776. Sept. 14, 1937. Fruit Manipulating Machine. H. D. Rey to The Anglo California National Bank of San Francisco, trustee.

U. S. Pat. 2,092,777. Sept. 14, 1937. Dried Fruit Processing. H. D. Rey to The Anglo California National Bank of San Francisco, trustee.

U. S. Pat. 2,094,083. Sept. 28, 1937. Dried Fruit Kneading Machine and Method. H. D. Rey to The Anglo California National Bank of San Francisco, Trustee.

U. S. Pat. 2,094,084. Sept. 28, 1937. Dried Fruit Softening Machine and Process. H. D. Rey to The Anglo California National Bank of San Francisco, Trustee.

U. S. Pat. 2,101,352. Dec. 7, 1937. Dehydrater. F. Y. Takenaga.

U. S. Pat. 2,107,798. Feb. 8, 1938. Method and Apparatus for Treating Dried Fruits. C. B. Pape, E. N. Thayer, and T. A. Schwarz.

U. S. Pat. 2,123,134. July 5, 1938. Process of Treating Food Materials. W. W. Cowgill to Sardik, Inc.

U. S. Pat. 2,124,895. July 26, 1938. Method of Preparing Pineapple. H. D. Rey to The Anglo California National Bank of San Francisco, trustee.

U. S. Pat. 2,127,474. Aug. 16, 1938. Method and Apparatus for (vacuum) Drying. F. S. Smith.

U. S. Pat. 2,128,697. Aug. 30, 1938. Drying Apparatus. J. Ettl to Potdevin Machine Co.

U. S. Pat. 2,132,656. Oct. 11, 1938. Flash Drying Control. A. R. Smith to Combustion Engineering Co.

U. S. Pat. 2,132,897. Oct. 11, 1938. Method and Apparatus for Drying Substances which Contain Liquids. J. G. W. Gentele.

U. S. Pat. 2,134,147. Oct. 25, 1938. Drying Apparatus. J. C. Rea to Dry Fruit Products Co.

U. S. Pat. 2,137,890. Nov. 22, 1938. Method for Treatment and Dehydration of Fleshy Plant Materials. E. F. Hopkins to free use of the Public.

U. S. Pat. 2,139,915. Dec. 13, 1938. Dried Fruit Process and Product. H. D. Rey to The Anglo California National Bank of San Francisco, trustee.

U. S. Pat. 2,140,788. Dec. 20, 1938. Treatment of Food Materials. W. W. Cowgill to Sardik, Inc.

U. S. Pat. 2,155,453. Apr. 25, 1939. Process of Preparing Fruit Products. C. R. Stuntz.

U. S. Pat. 2,172,059. Sept. 5, 1939. Apparatus for Dehydrating Food Products. F. S. Chilton.

U. S. Pat. 2,185,129. Dec. 26, 1939. Process for Dehydrating Comminuted Potatoes and Root Crops. K. Maus.

U. S. Pat. 2,186,282. Jan. 9, 1940. Apparatus for Treating Material. W. W. Cowgill to Sardik, Inc.

U. S. Pat. 2,190,063. Feb. 13, 1940. Dehydrated Mashed Potatoes. O. Gano, to Potato Corp. of Idaho.

U. S. Pat. 2,192,041. Feb. 27, 1940. Method of Treating and Preparing Vegetables. O. Headland.

U. S. Pat. 2,199,815. May 7, 1940. Apparatus for the Treatment of Biologically Active Products. E. W. Flosdorf, assignor to the Trustees of the Univ. of Penn.

U. S. Pat. 2,215,265. Sept. 17, 1940. Apparatus for the Concentration and Preservation of Food Products and Biological Substances. E. W. Flosdorf.

U. S. Pat. 2,225,627. Dec. 24, 1940. Method for the Concentration and Preservation of Food Products and Biological Substances. E. W. Flosdorf assignor to F. J. Stokes Machine Co.

U. S. Pat. 2,274,905. Mar. 3, 1942. Method for Dehydrating and Curing Vegetable Materials. L. W. Lewis.

U. S. Pat. 2,278,466. Apr. 7, 1942. Quickly Disintegratable Bonded Food Unit and Method of Making it. A. Musher.

U. S. Pat. 2,278,472. Apr. 7, 1942. Dehydrated Prefrozen Food Product. A. Musher.

U. S. Pat. 2,279,280. Apr. 7, 1942. Method for Preparing Dehydrated Peas and Beans. A. Musher.

U. S. Pat. 2,284,913. June 2, 1942. Drying Fruits, Vegetables, Fish, Meats, etc. A. H. McComb.

U. S. Pat. 2,288,616. July 7, 1942. Apparatus for Dehydration of Various Vitaminic Foods, Beverages, etc. B. G. Freund, (50 per cent to Hurda A. White.)

U. S. Pat. 2,290,470. July 24, 1942. Method of and Apparatus for Dehydrating Liquid Products. J. M. Hall. Assignor to Drying and Concentrating Co.

U. S. Pat. 2,292,447. Aug. 11, 1942. Foods Dehydrated Under Vacuum at Freezing Temperatures. J. C. Irwin, to U. S. Cold Storage Corp. and D. C. Pfeiffer and J. M. Hill.

U. S. Pat. 2,293,728. Aug. 25, 1942. Vegetables and the Like Ground into Uniformly Sized Small Particles Preparatory to Multistage Dehydration. B. G. Freund.

U. S. Pat. 2,294,530. Sept. 1, 1942. Fruits and Vegetables Dehydrated in Tray-equipped Compartmented Unit Through which Temperature and Humidity-Conditioned Air is Circulated. B. Wiese.

U. S. Pat. 2,301,589. Nov. 10, 1942. Drying of Fruit Pulp. W. G. Shepard.

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